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DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150814

SOLAR SYSTEM INSTALLATION AT LOUISVILLE, KENTUCKY (Final Report)

Prepared from documents furnished by

Rademaker Corporation
Louisville, Kentucky

Under ERDA Contract E(49-18)-2385

Monitored by

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy

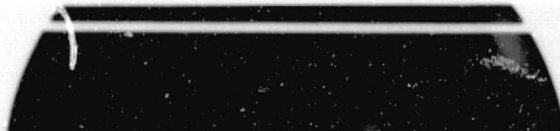
(NASA-CR-150814) SOLAR SYSTEM INSTALLATION
AT LOUISVILLE, KENTUCKY Final Report
(Rademaker (Richard L.), Corp.) 105 p HC
A06/MF A01

N79-10518

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U.S. Department of Energy



Solar Energy

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16. ABSTRACT A contract for \$29,729 was awarded in June 1976 for the installation of a solar space heating and domestic hot water system at 2400 Watteroon Trail, Louisville, Kentucky, in cooperation with ERDA, now the Department of Energy (DOE). The overall philosophy used by the designer, builder, and installer, Mr. Richard W. Rademaker, President of Rademaker Corporation, was to install both a liquid and a hot air system retrofitted to his existing office and combined warehouse building. The 1080 sq. ft. office space is heated first and excess heat is dumped into the warehouse. Since solar heating is a business, hobby, and way of life to Mr. Rademaker, the two systems offered a unique opportunity to measure the performance and compare results of both air and liquid at one site. The final report describes in detail the two solar systems. Information on the data acquisition system has been added to this report by the MSFC Technical Manager.			
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SECTION I

GENERAL

SOLAR HEATING DEMONSTRATION PROJECT

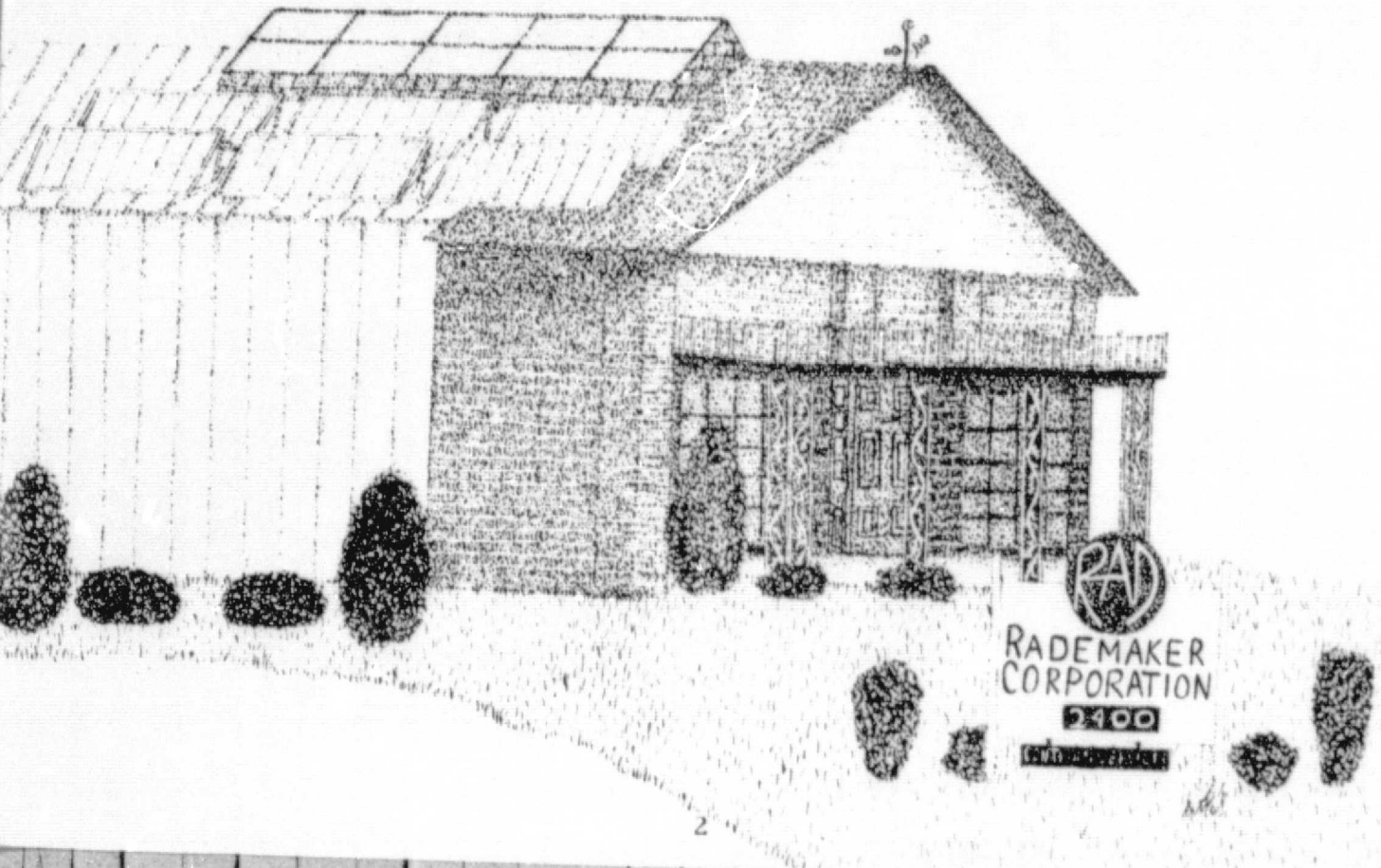
RADEMAKER CORPORATION LOUISVILLE, KENTUCKY

FUNDED UNDER CONTRACT WITH ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DIVISION OF SOLAR ENERGY

PROGRAM OPPORTUNITY NOTICE DSE-75-2

CONTRACT NUMBER E(49-18) 2385

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A. PROJECT INFORMATION:

BUILDING: Existing office warehouse built in 1969. Structure is steel Butler Building with masonry front.

CLIMATIC DATA: Latitude 38°. Total annual degree days 4660; for January only, 930. Average winter temperature 42°.

USEFUL HEAT GAIN AVAILABLE FROM COLLECTORS DURING MONTH OF JANUARY: 16,120 BTU per square foot.

B. BUILDING AND PROJECT DESCRIPTION:

Occupant of building is Rademaker Corporation, Bluegrass Industrial Park, Louisville, Kentucky. Building was constructed in 1969. It is a Butler Building with a total area of 10,000 square feet. The front portion of the building is office space with 1080 square feet of ground cover. The front wall of the office is brick veneer with relatively large glass area. The solar heating system described herein is for space heating and for heating domestic hot water. Two systems are employed, one is a liquid heating system employing ethylene glycol through six collectors of 40 square feet each inclined at 53°, facing south. The second system is an air collector system employing ten panels of 19½ square feet each inclined at 33°, facing south. The liquid system uses a 560 gallon water tank for storage. The air system uses 110 cubic feet of one inch diameter washed river gravel for storage.

The auxiliary energy employed to heat the building is natural gas. The solar heating system is in fact a retrofit to the gas heating system which was installed in the building during its original construction.

C. SEQUENCE OF OPERATION:

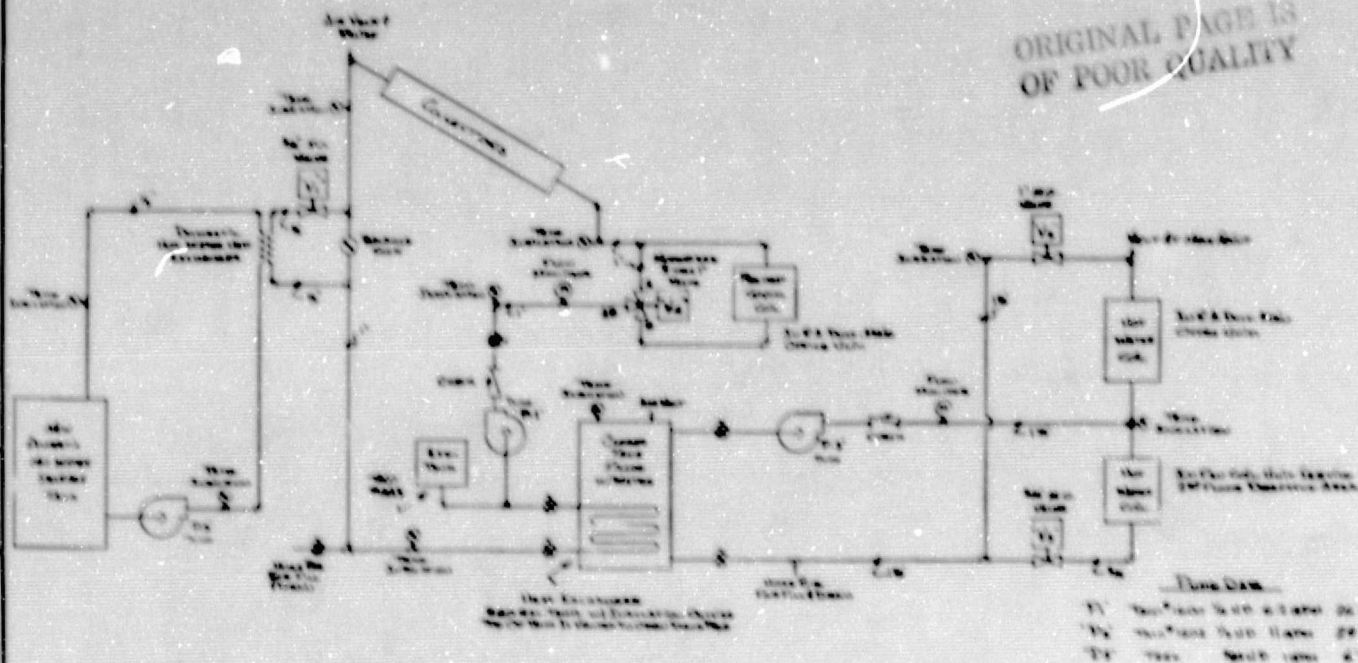
The liquid system employs a heat exchanger built into the hot water storage tank which allows ethylene glycol to pump through the collectors when solar radiation is available introducing heat to the stored water. A pump is provided in the stored water loop which will pump water from the storage tank to the hot water coils of either of two air handlers when heat is demanded in the space. Control valves in each of the hot water coil circuits are operated from thermostats to allow water to flow to either or both of the water coils upon demands of their respective thermostats.

Domestic hot water is heated from the glycol circuit by a heat exchanger. The motor operated valve in the heat exchanger circuit controls the maximum temperature to which the domestic hot water can be heated.

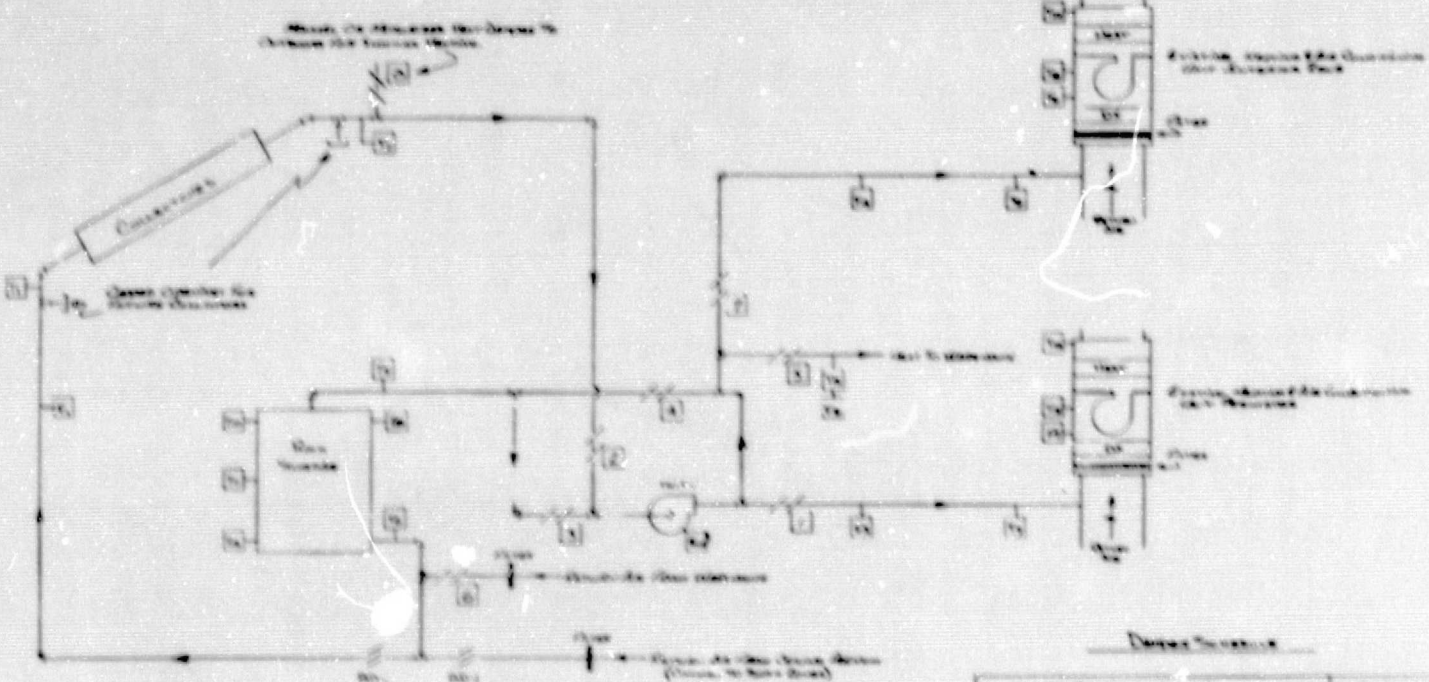
A preheat glycol coil is provided in the perimeter office zone air handler to allow the glycol to be passed through the preheat coil to serve as an economizer within the glycol circuit allowing the glycol to flow in series from the heat exchanger within the storage tank to the preheat coil then back to the collector provided that the storage water temperature has reached a predetermined minimum temperature.

The air collector system employs eight dampers, all of which are motor operated together with a booster fan to introduce the air to the collectors and/or the rock storage bin to the respective air handling system for distribution to the space.

Return air taken from the space is allowed to flow through the collectors as long as radiant heat is available then through the booster fan and into the respective zone requiring heat. If no zones demand heat, the dampers position themselves to allow flow from the collector through the rock storage thus charging the rock storage with heat. When heat is not available at the collectors, but is present in the rock storage and is demanded by the space, the booster fan will draw air, counterflow, from the rock storage bin and pass it into the respective zone demanding heat. If excess heat exists and if heat is demanded in the warehouse, heat will be passed from the collectors or from the rock storage bin into the warehouse provided that no heat is demanded within the office space.



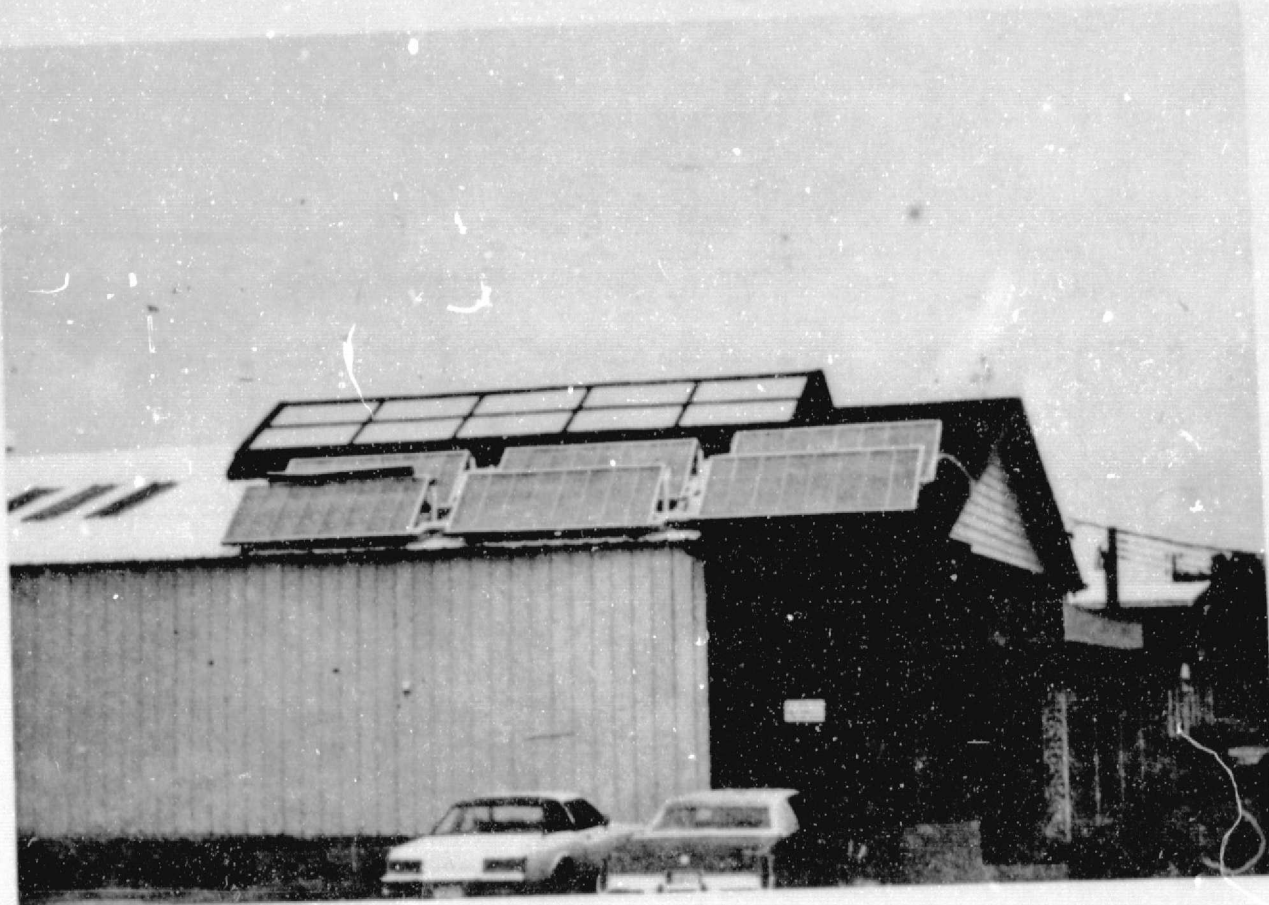
Schematic Diagram of Liquid Collection System
(No. 1)



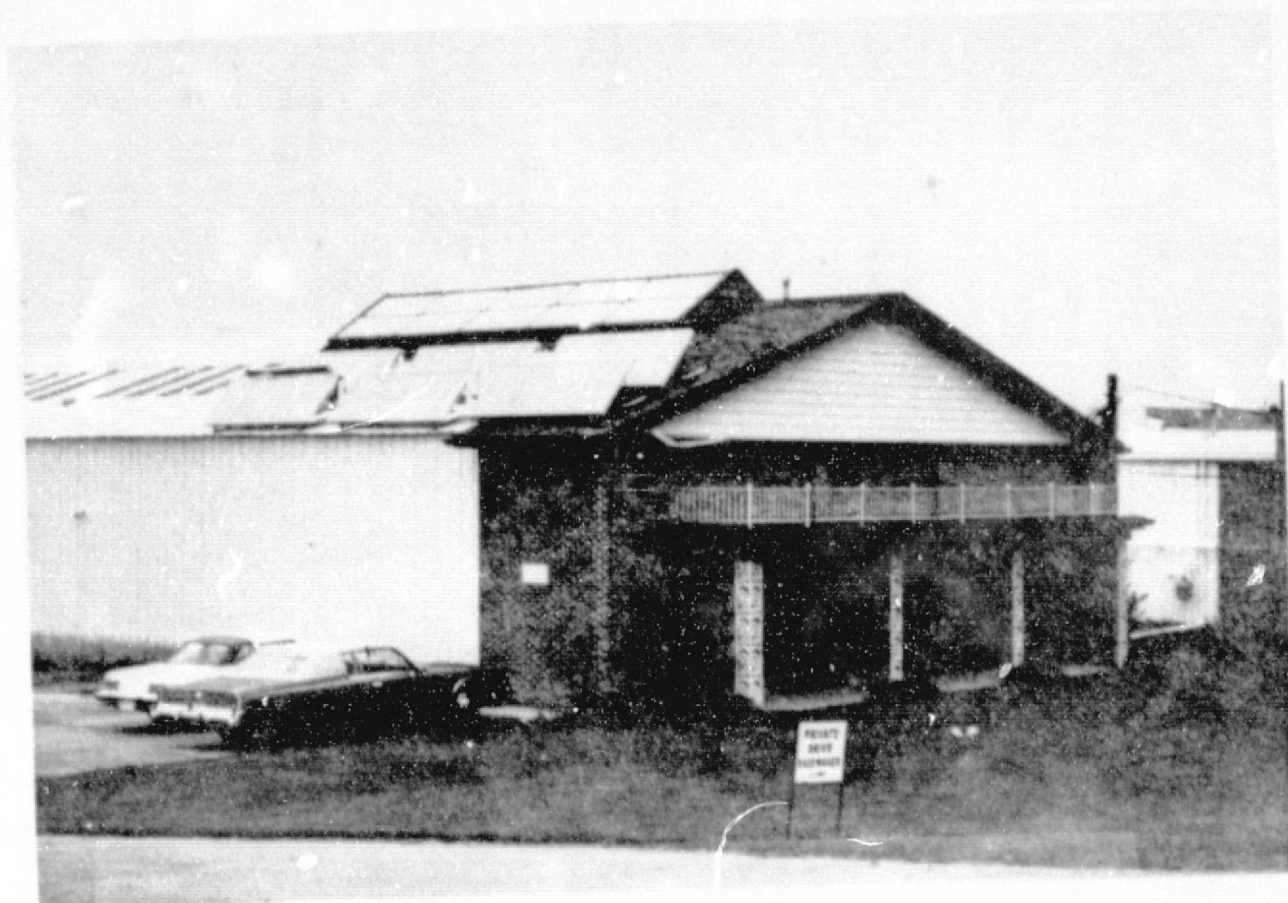
Schematic Diagram of Liquid Collection System
(No. 2)

Component (Symbol)	Location	Size	Material	Notes
Main Storage Tank	Top Left	12" x 12" x 12"	Steel	See Notes
No. 1 Storage Tank	Bottom Left	12" x 12" x 12"	Steel	See Notes
No. 2 Storage Tank	Bottom Right	12" x 12" x 12"	Steel	See Notes
No. 3 Storage Tank	Top Right	12" x 12" x 12"	Steel	See Notes
No. 4 Storage Tank	Bottom Center	12" x 12" x 12"	Steel	See Notes
No. 5 Storage Tank	Top Center	12" x 12" x 12"	Steel	See Notes
No. 6 Storage Tank	Bottom Right	12" x 12" x 12"	Steel	See Notes
No. 7 Storage Tank	Top Right	12" x 12" x 12"	Steel	See Notes
No. 8 Storage Tank	Bottom Right	12" x 12" x 12"	Steel	See Notes
No. 9 Storage Tank	Top Right	12" x 12" x 12"	Steel	See Notes
No. 10 Storage Tank	Bottom Right	12" x 12" x 12"	Steel	See Notes

Schematic Diagram of Liquid Collection System
(No. 3)

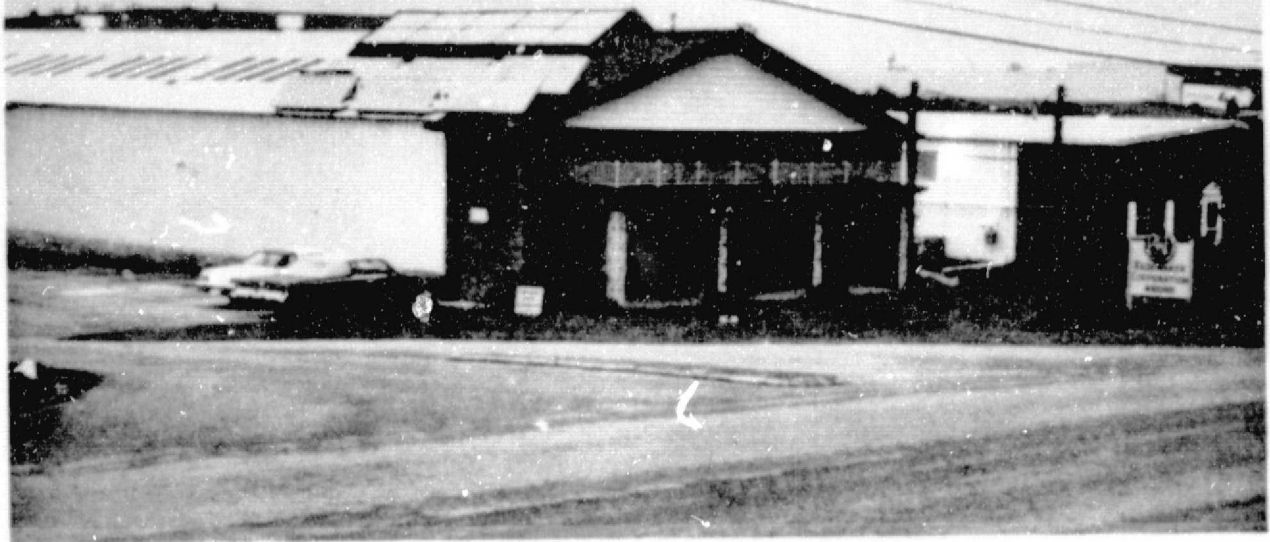


RADCO - Outside View Looking North

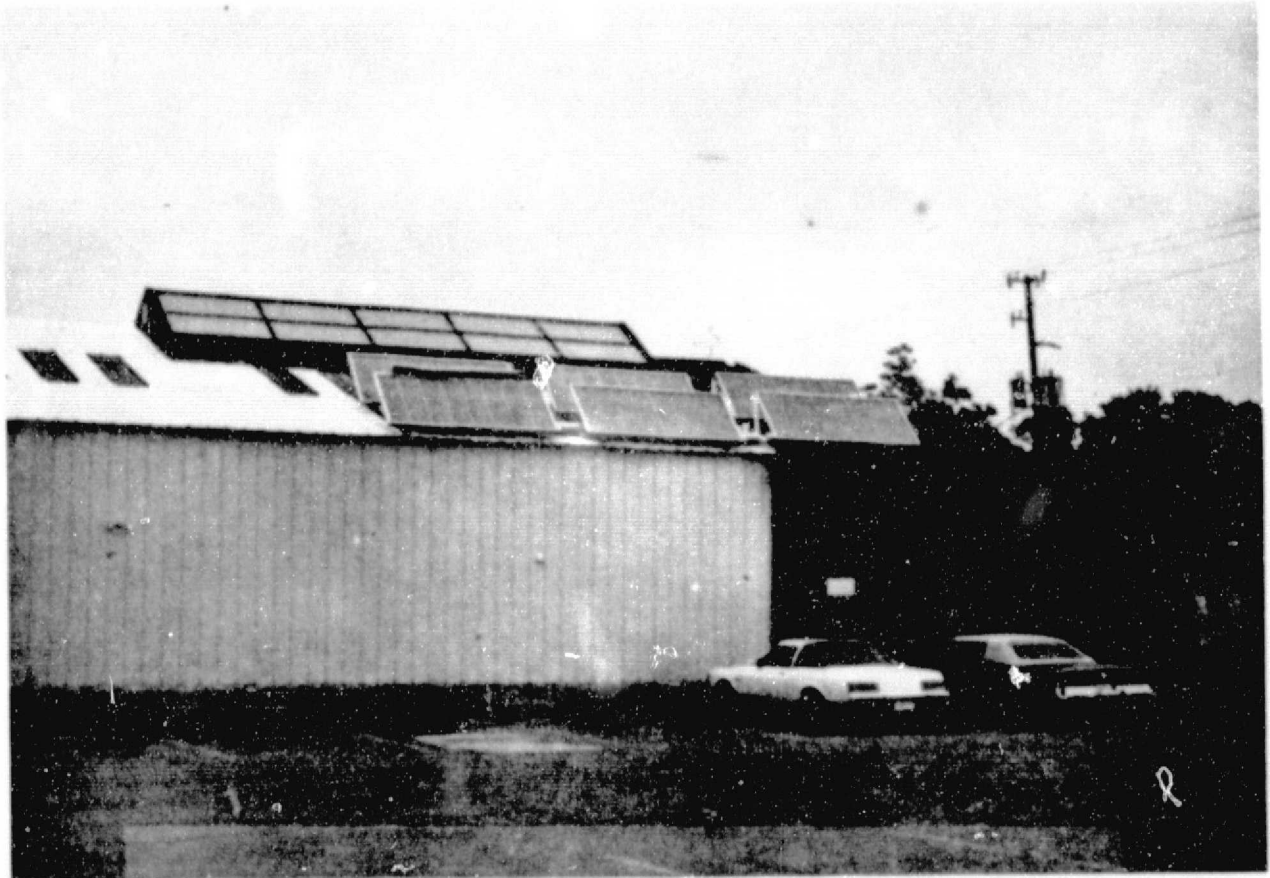


RADCO - Outside View Looking North

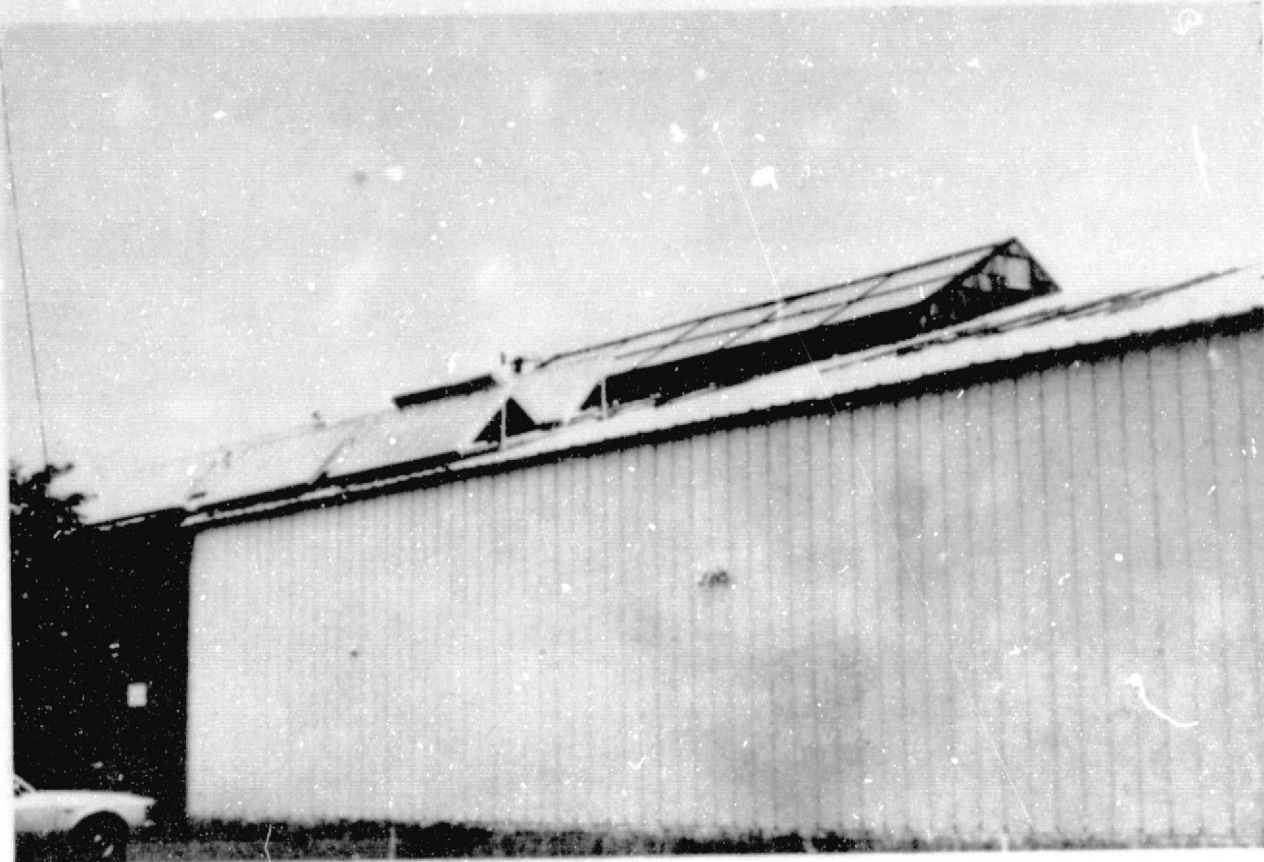
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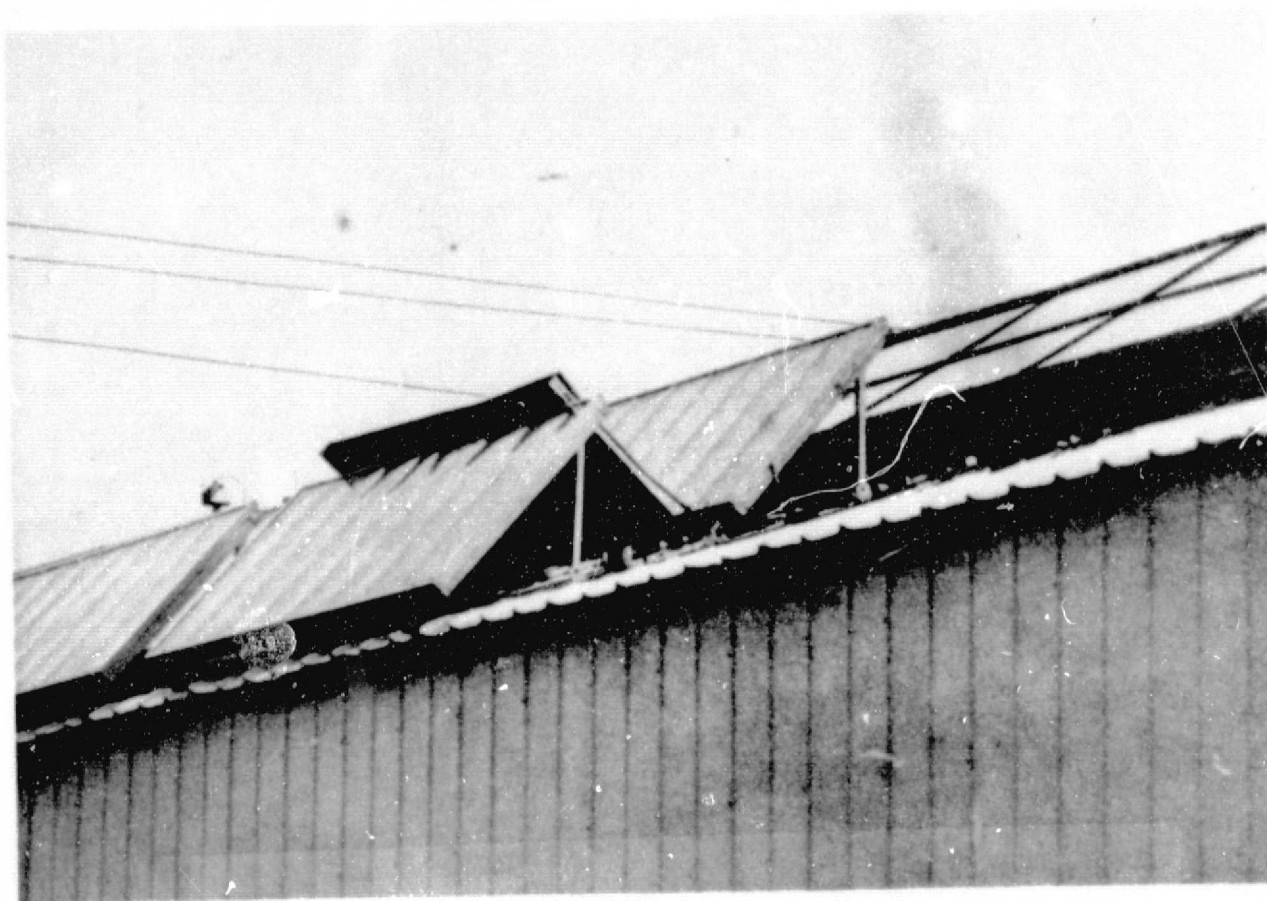
RADCO - Outside View Looking North



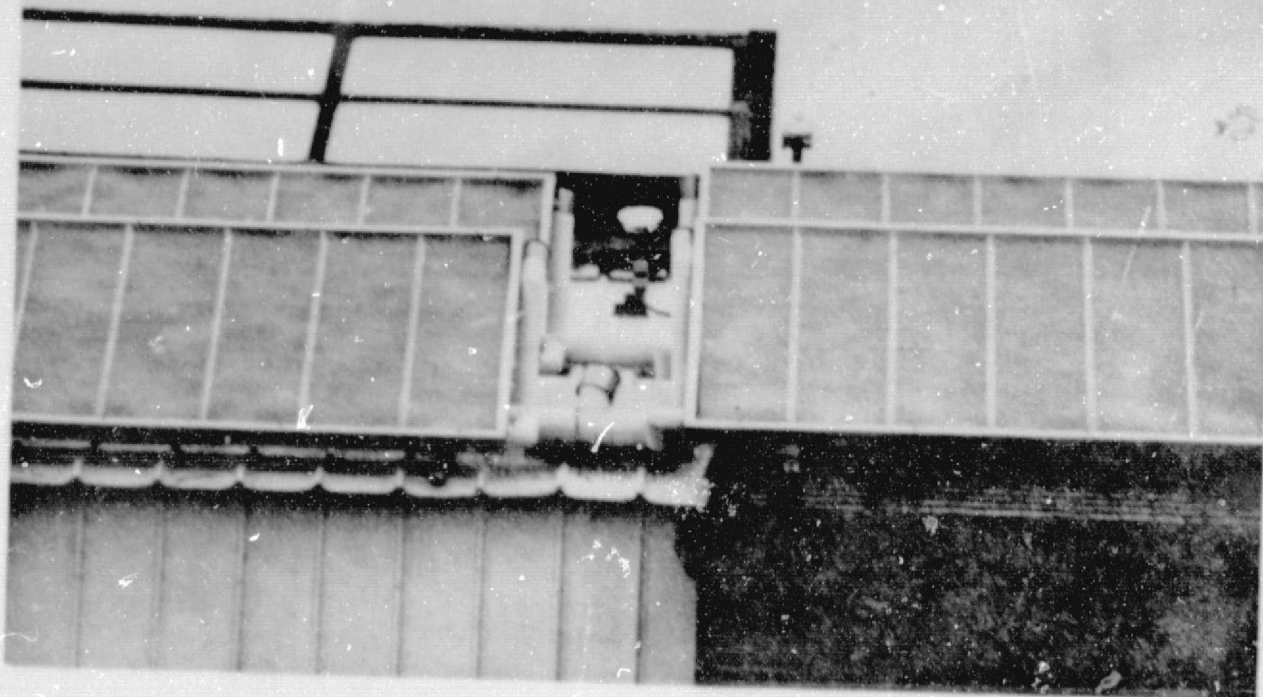
RADCO - Outside View Looking North



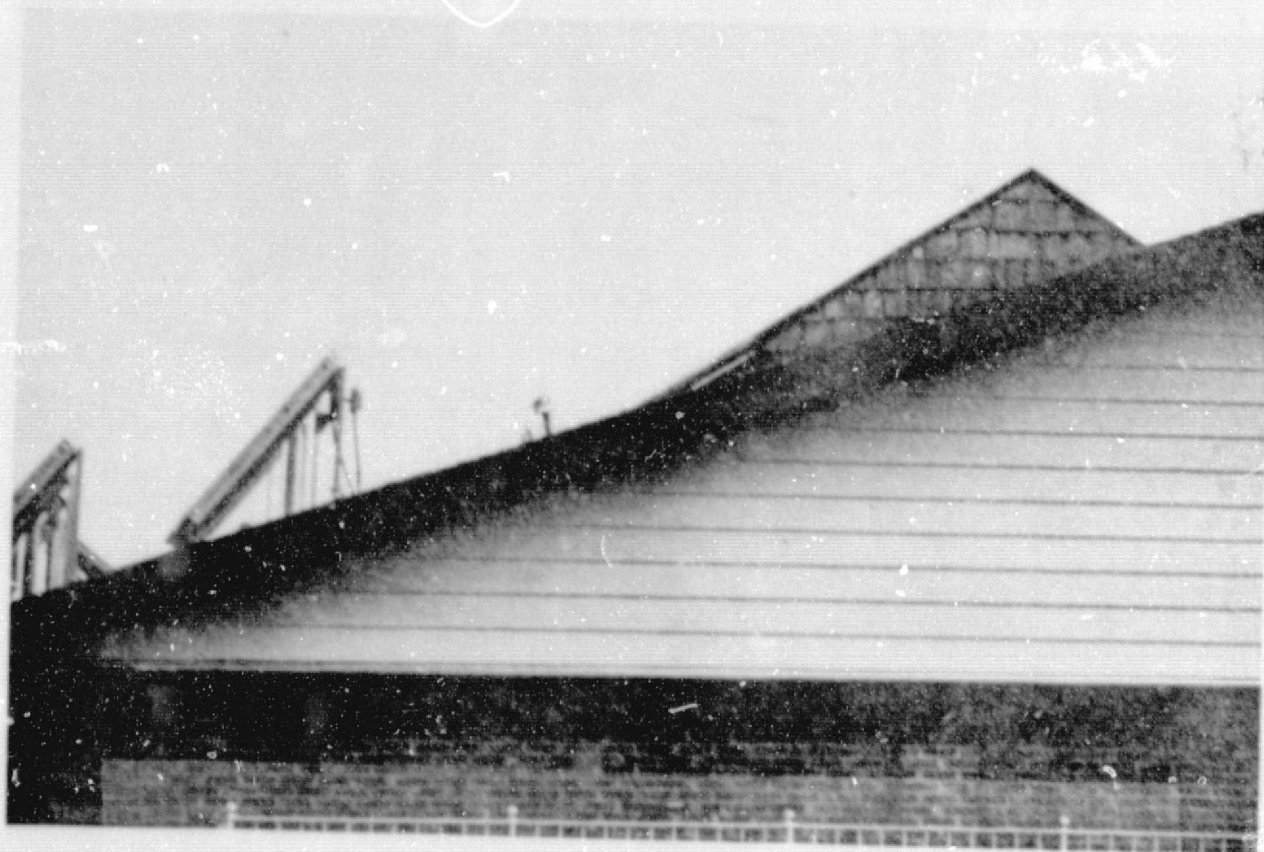
RADCO - Outside View Looking North



Collector Close Up (See Reflector)



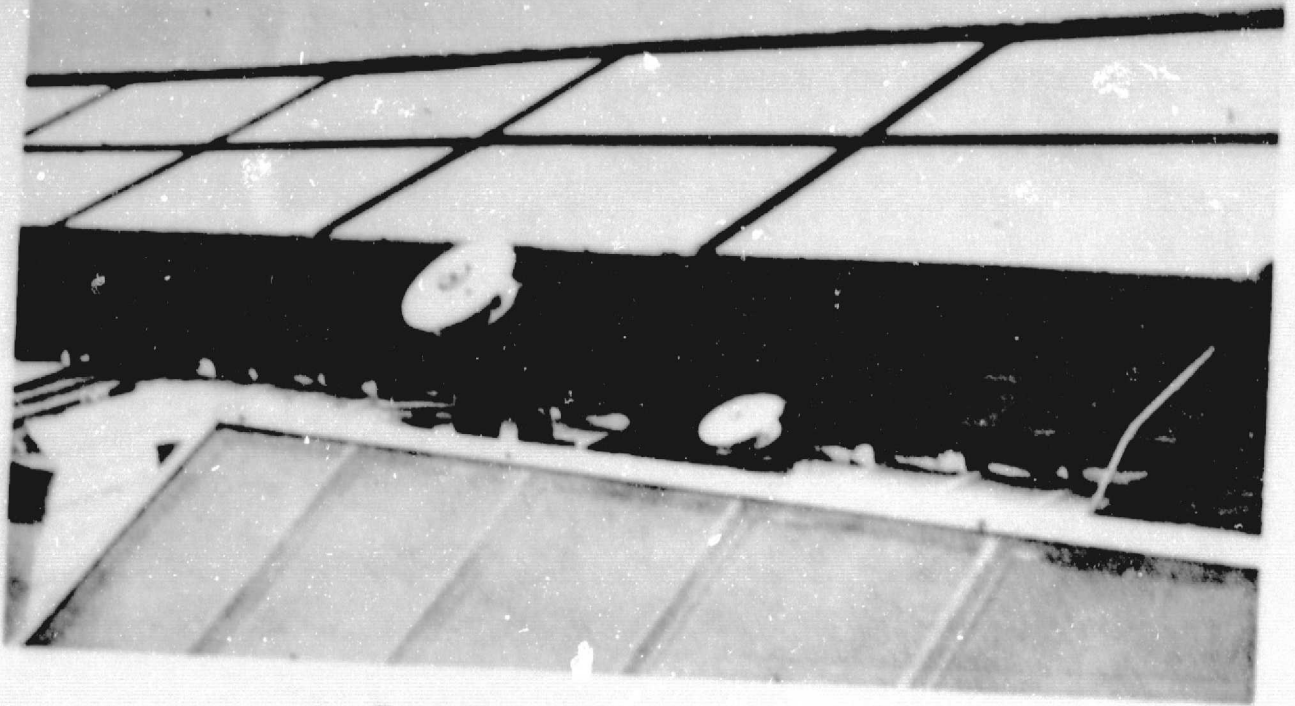
Collectors Close Up



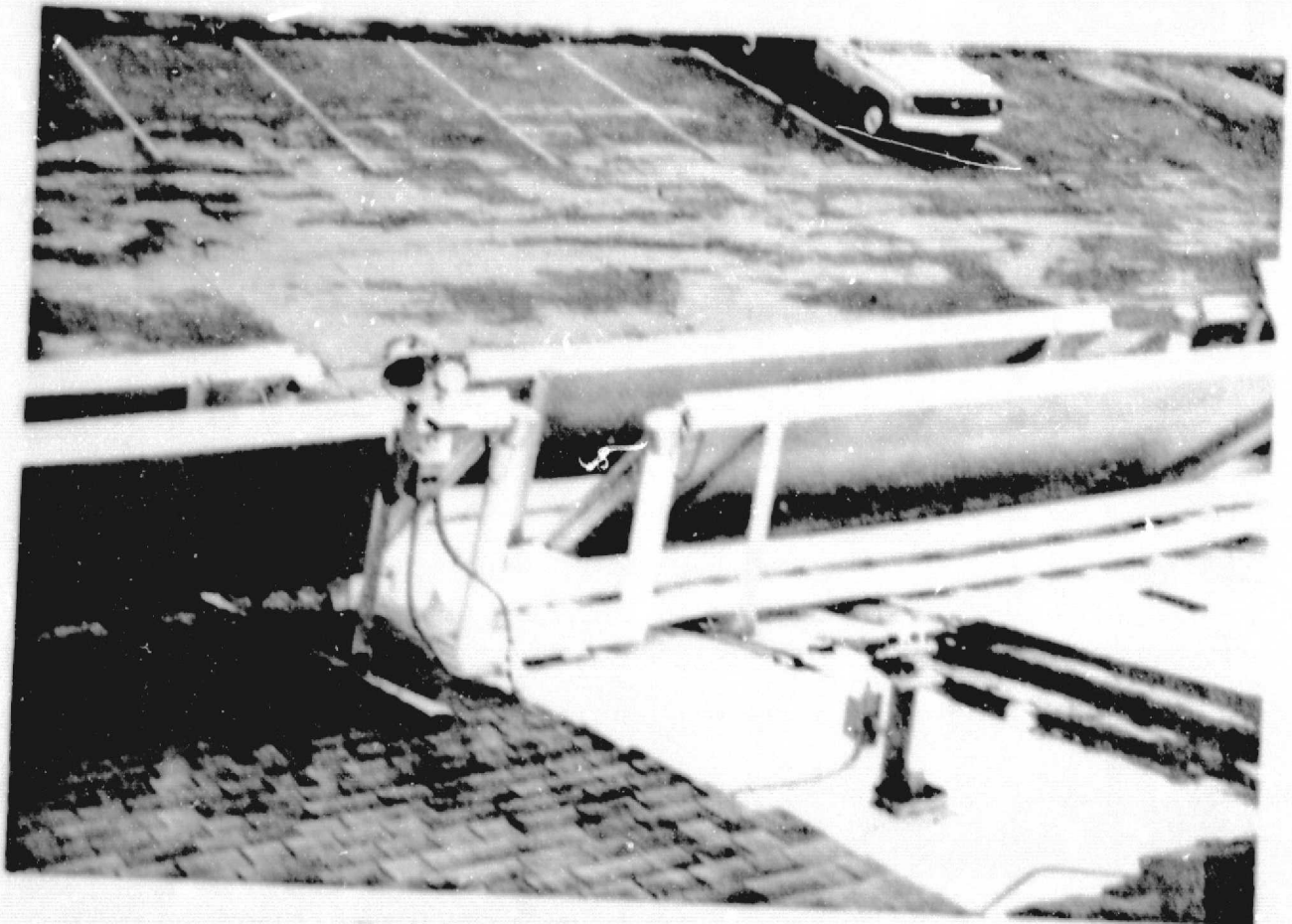
Collectors - Front of Building Looking West



Collectors on Roof Looking West



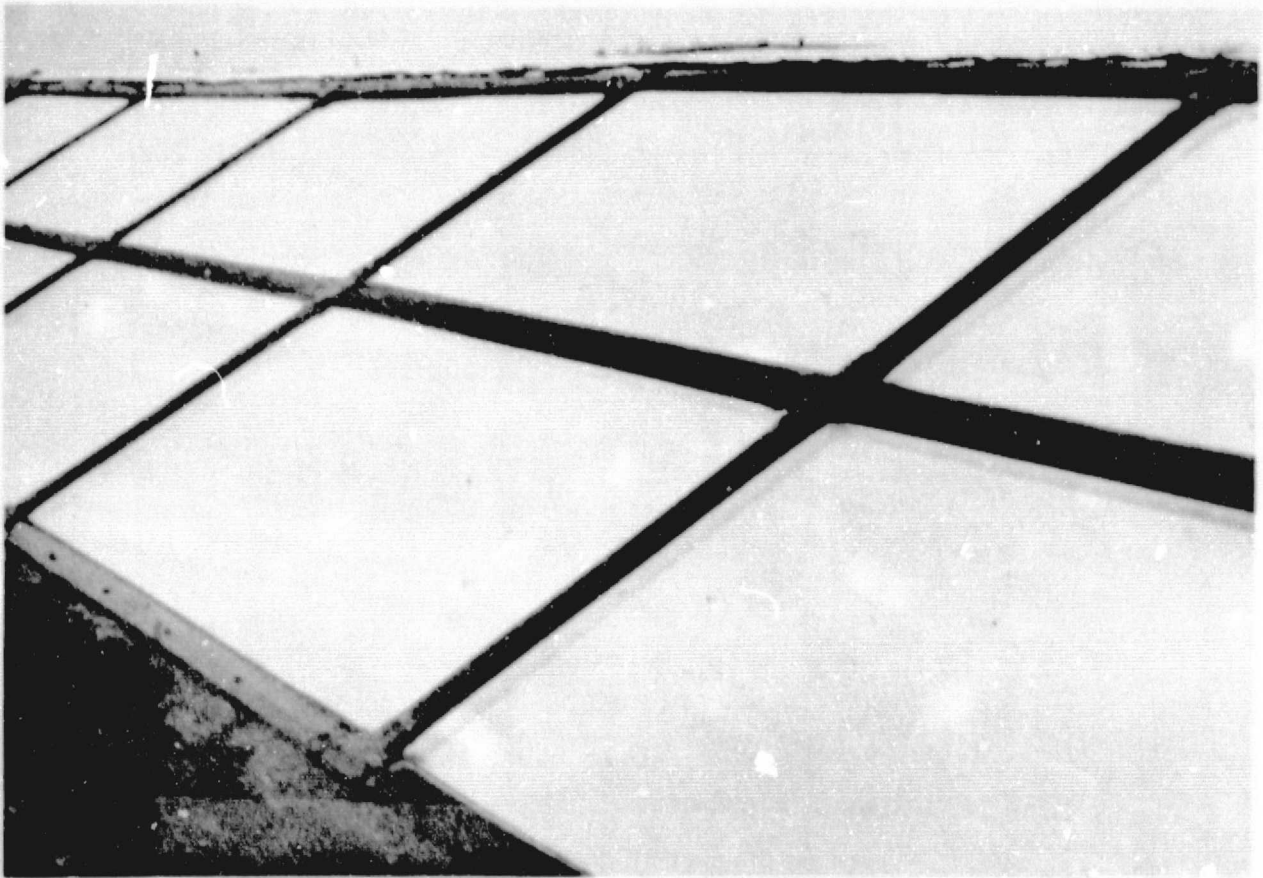
Roof View of Air Collectors



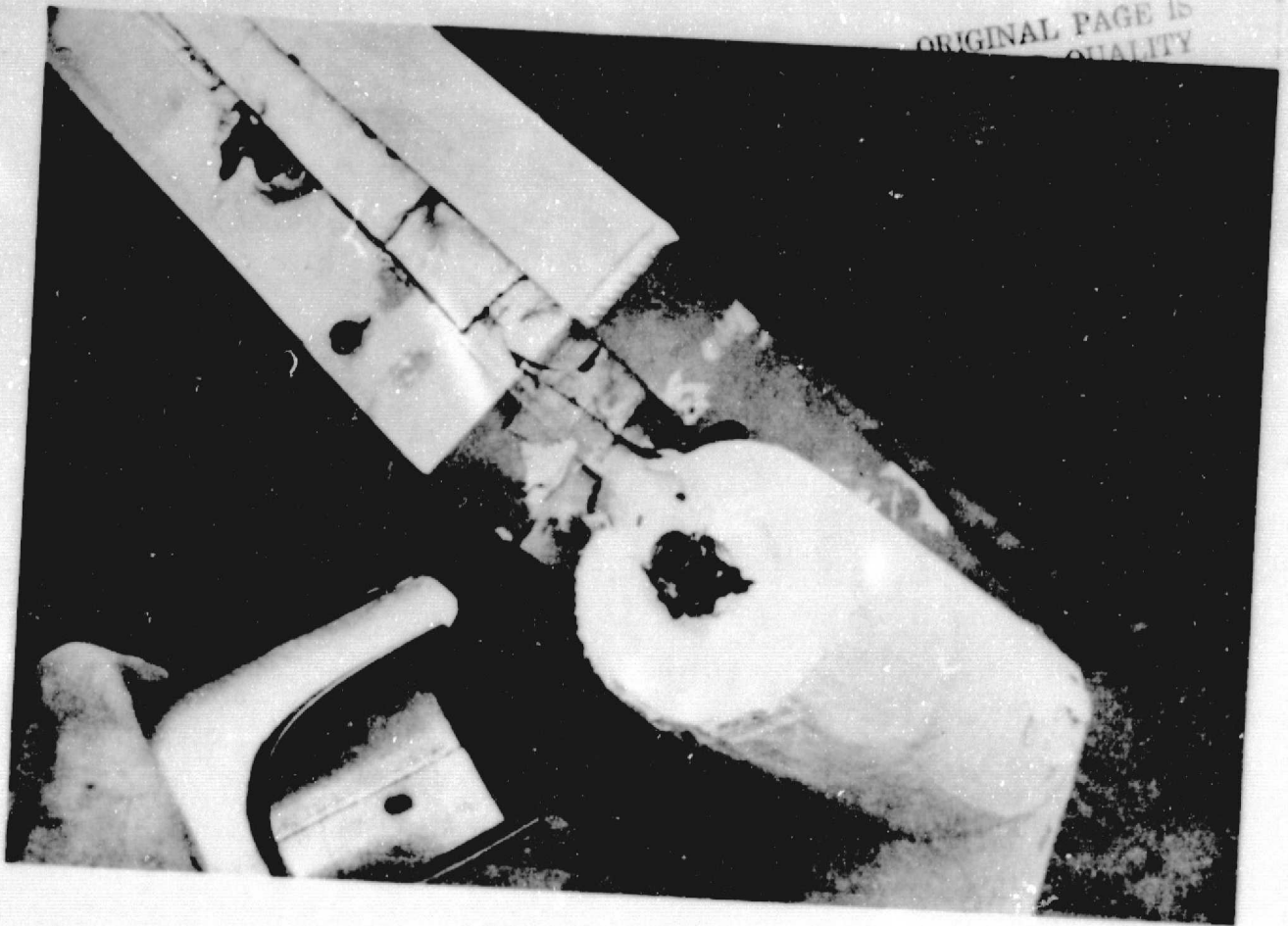
Back View of Liquid Collectors



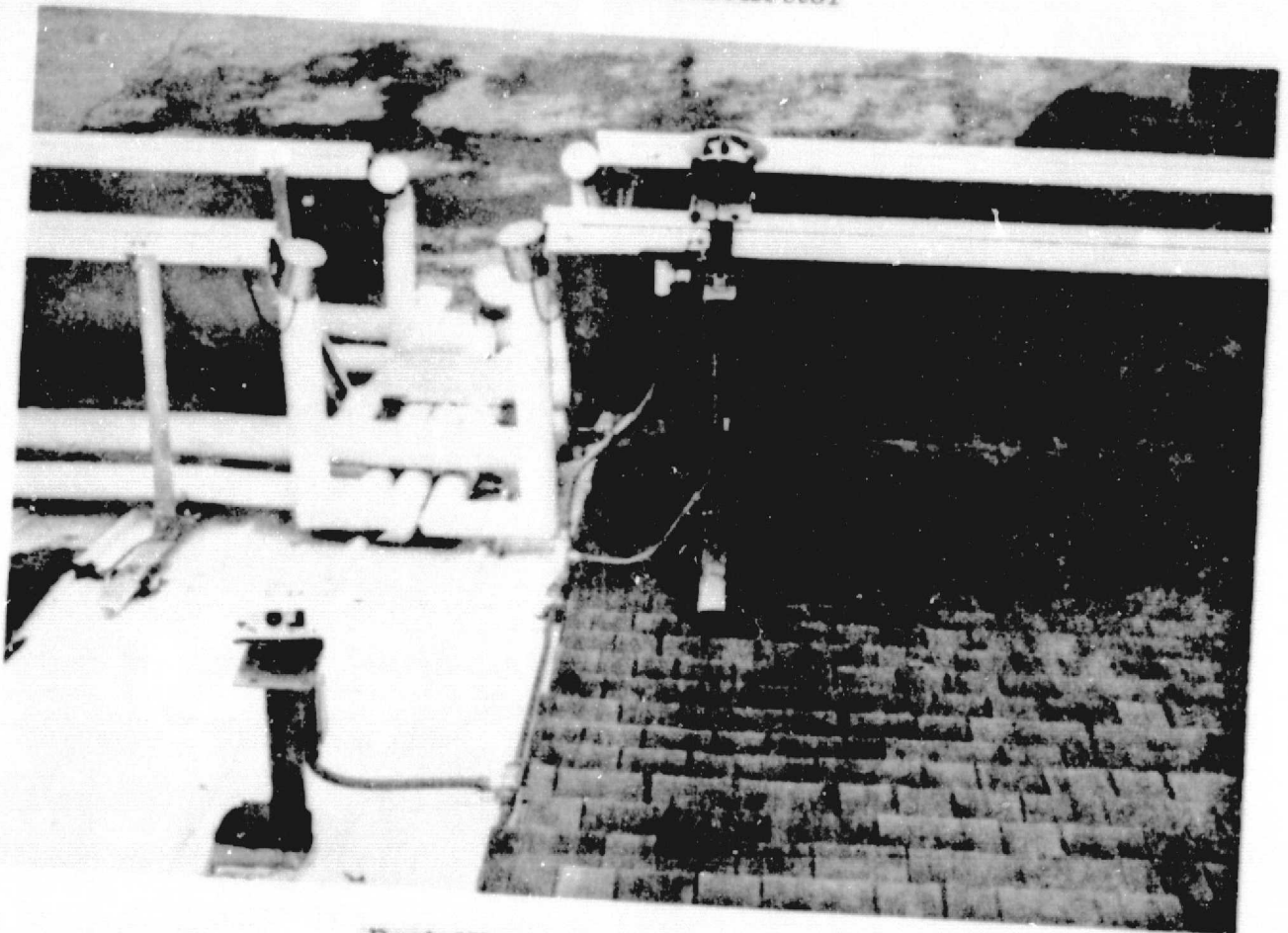
End View of Air Collectors Looking W. S. W.



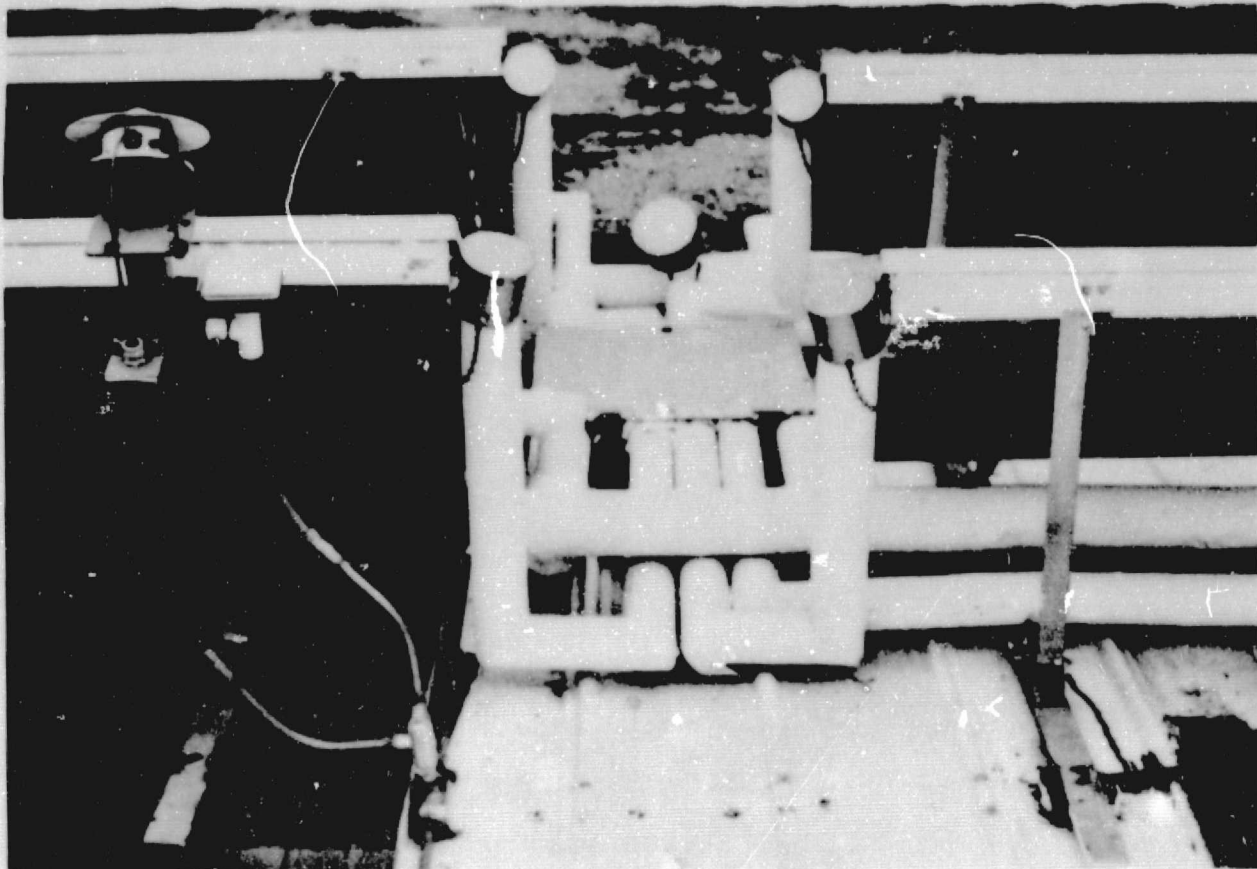
Close Up of Air Collectors



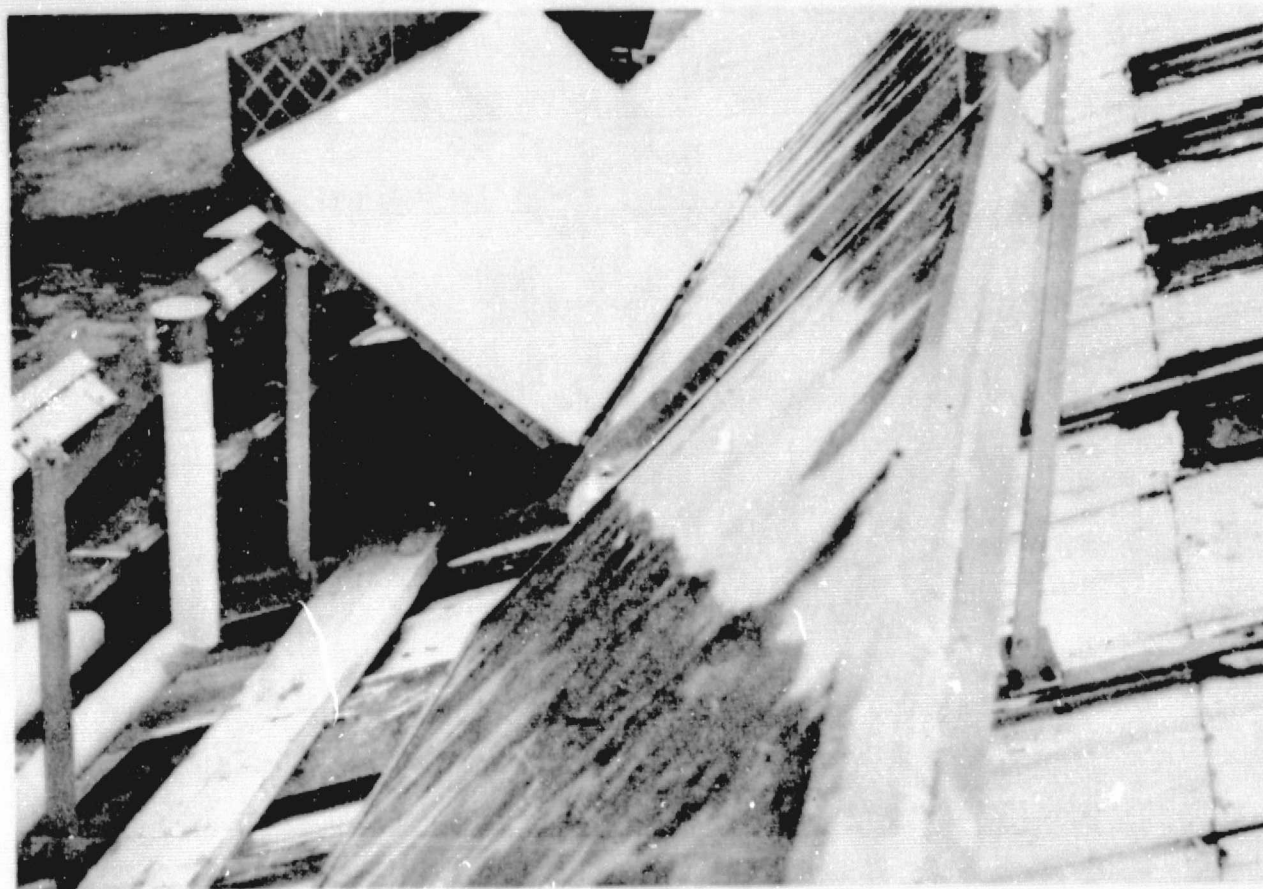
Air Vent on Collector



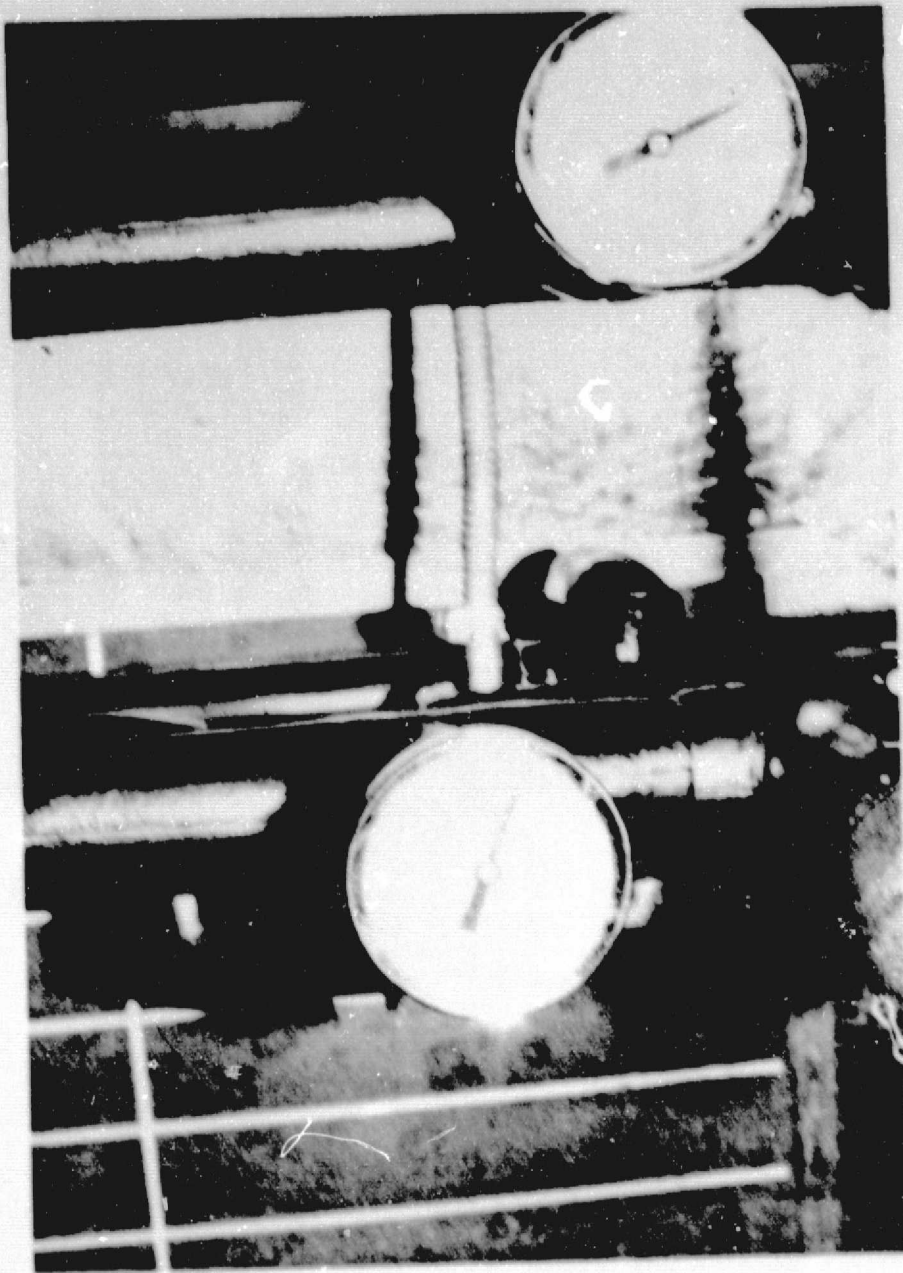
Back View on Liquid Collectors



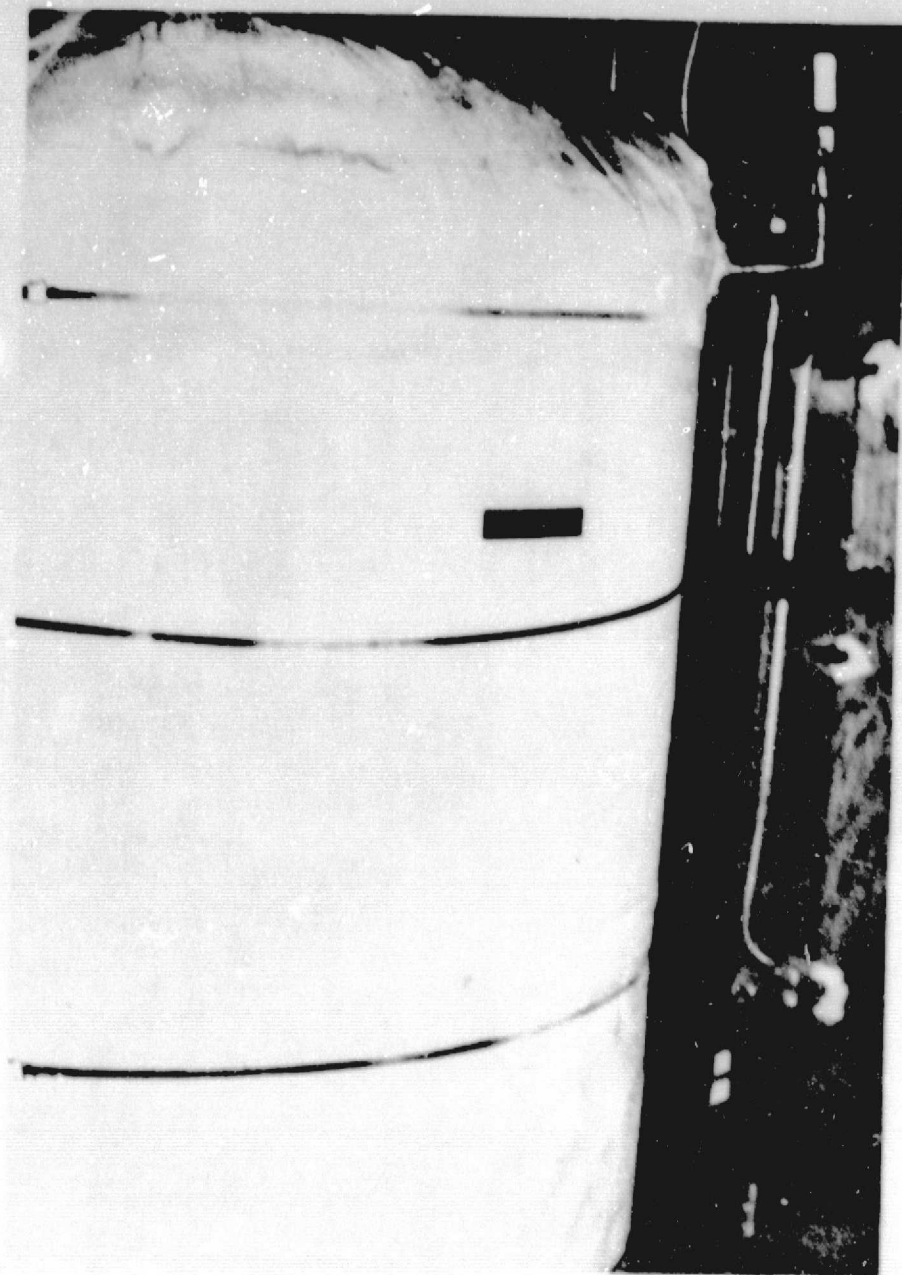
Back View of Liquid Collectors



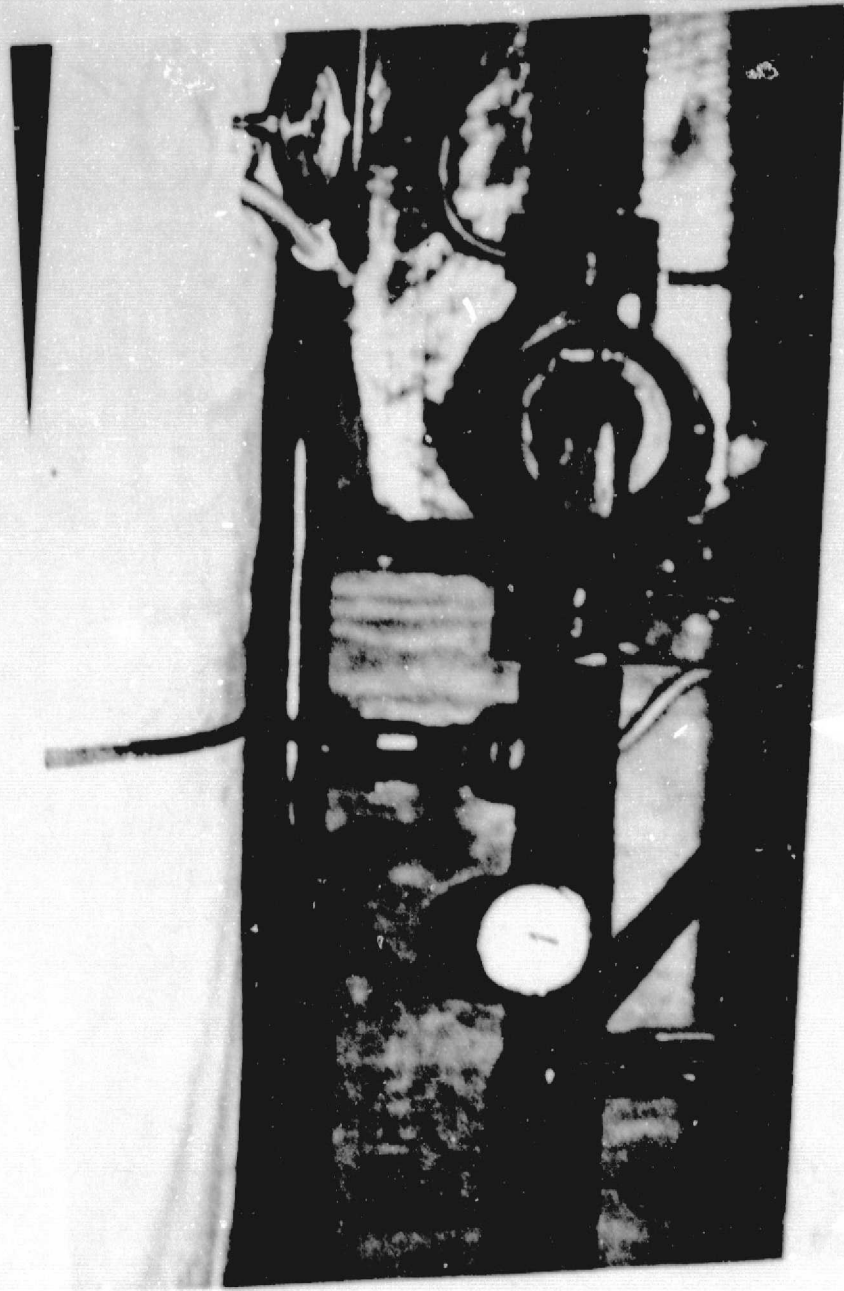
Close Up of Reflector Looking West



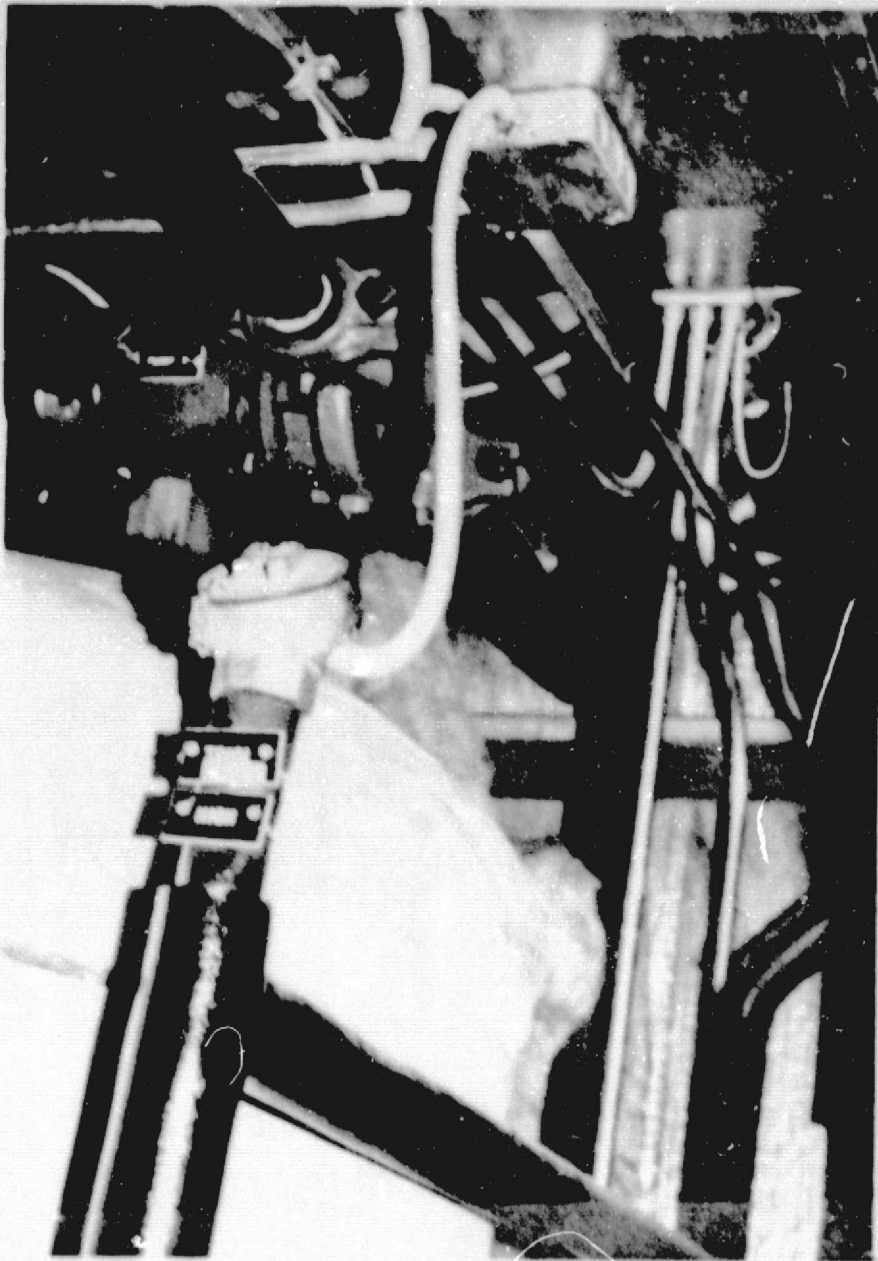
Temperature Gauges Showing Glycol Discharge
Temperature - Upper Gauge with Reflector



Water Storage Tank - 560 Gallon

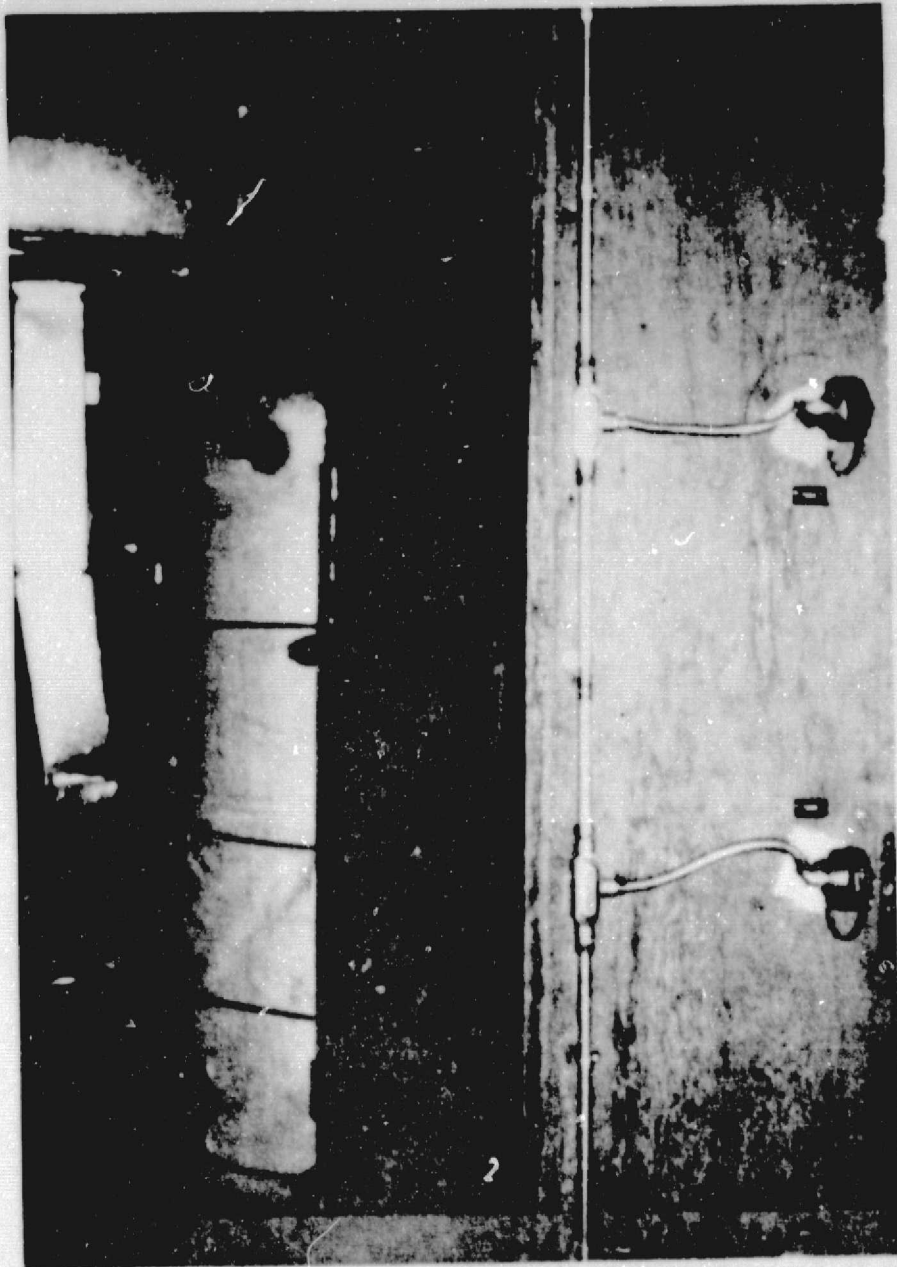


Glycol Pump P-1 & Pressure Gauge

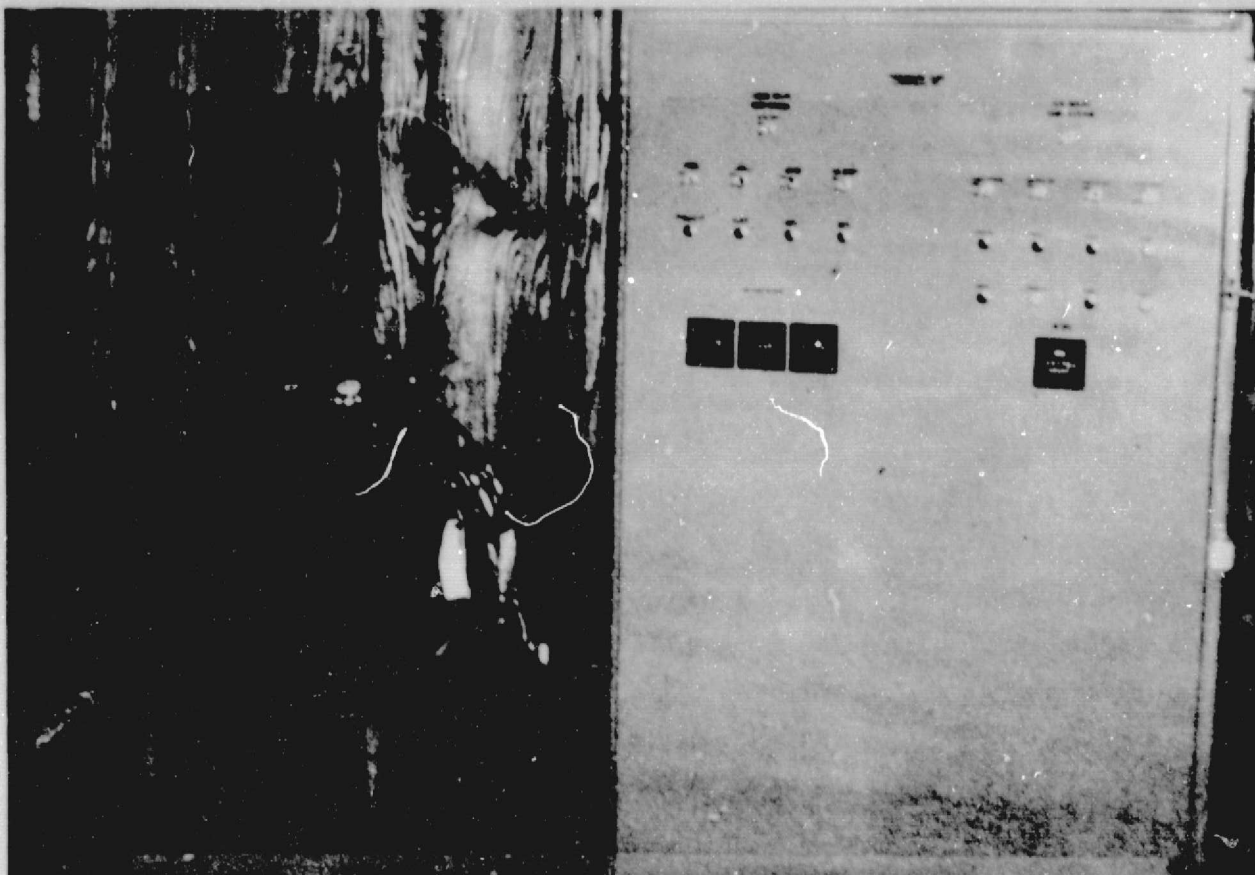


Pump P-2

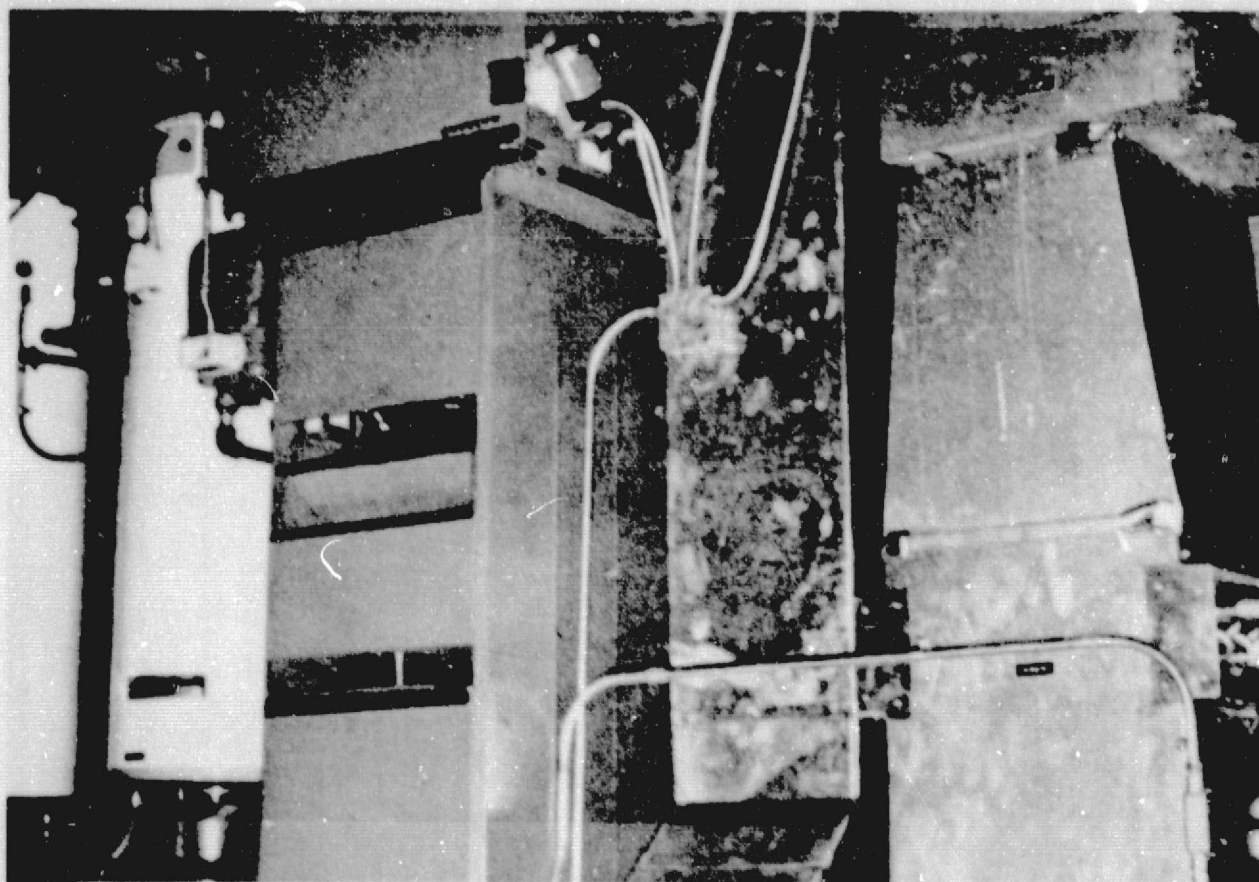
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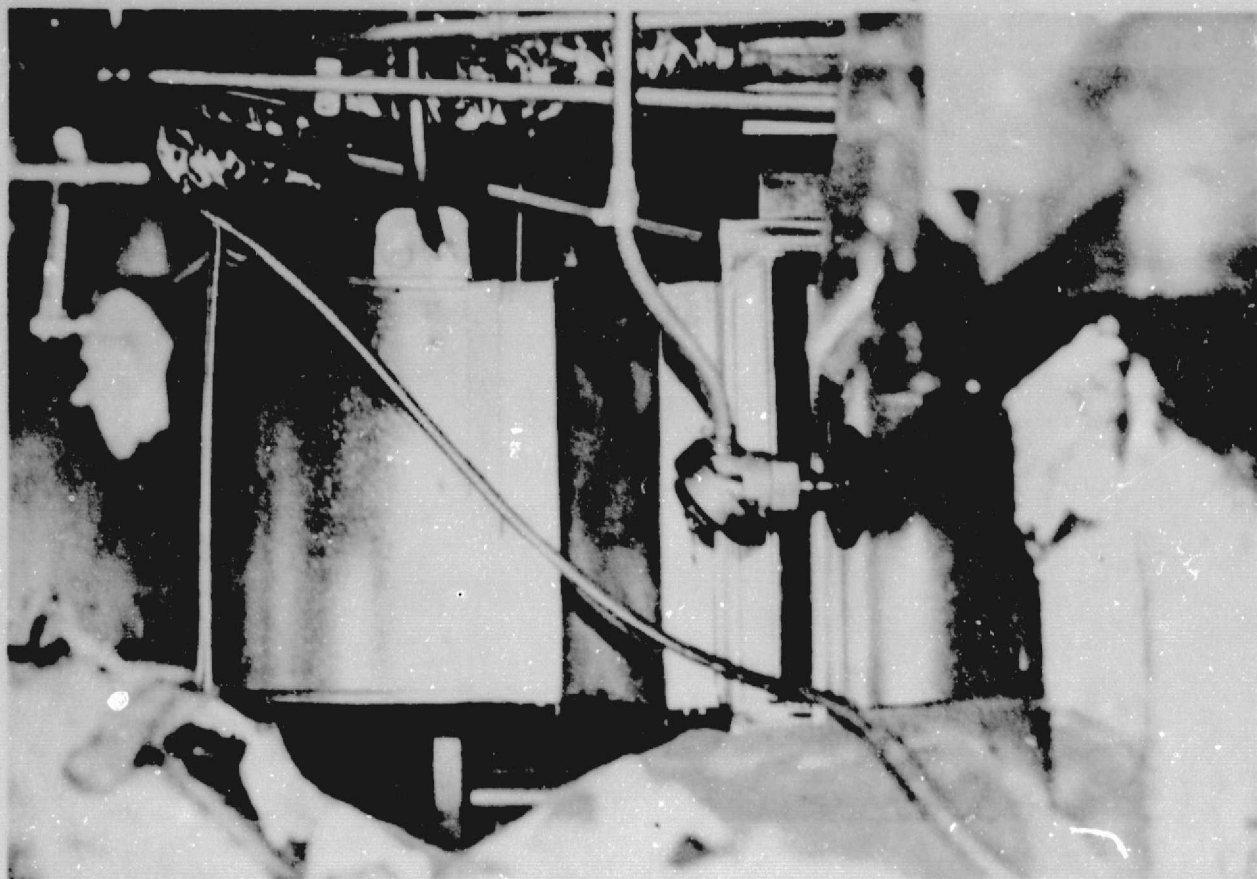
Rock Box



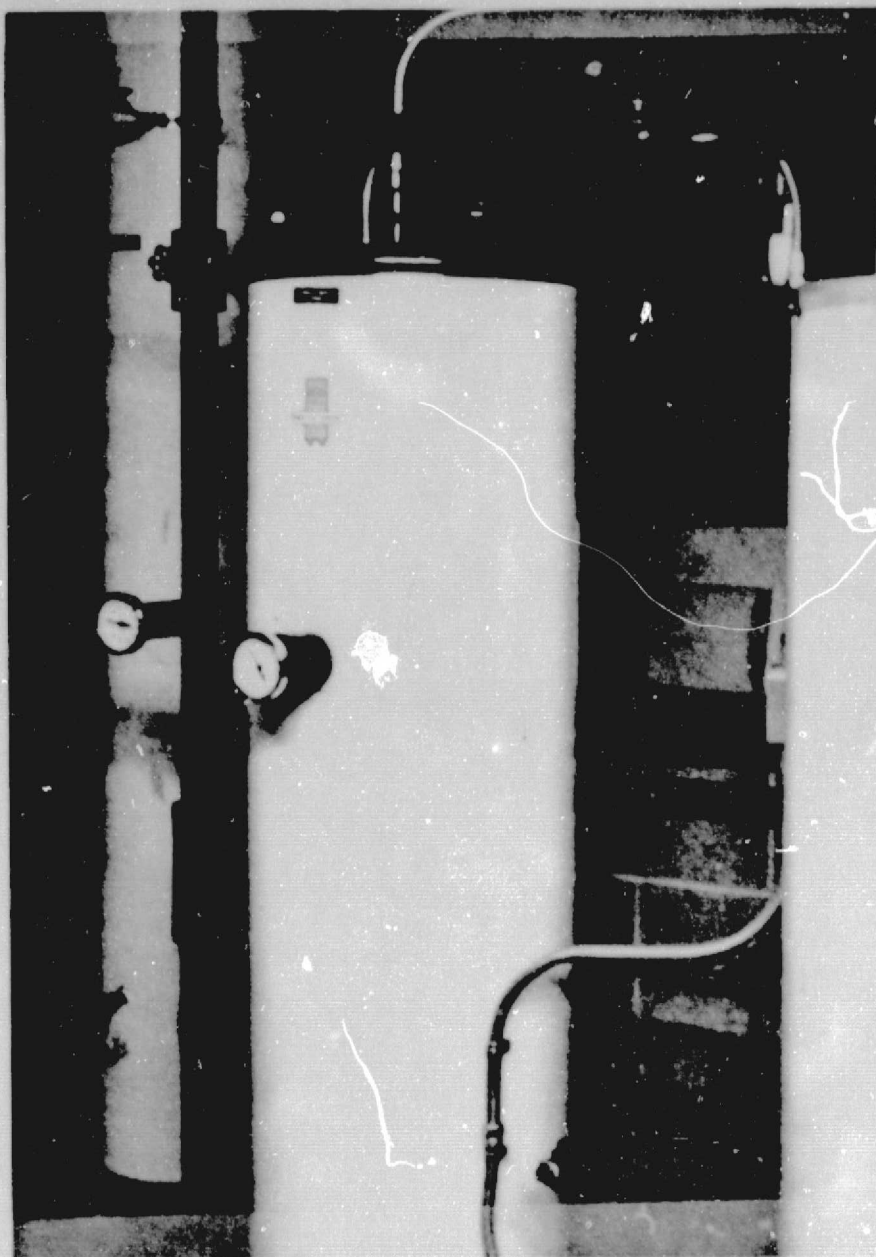
Temperature Control Panel



Perimeter Zone Return Air Duct and Counterflow Furnace and Water Heaters

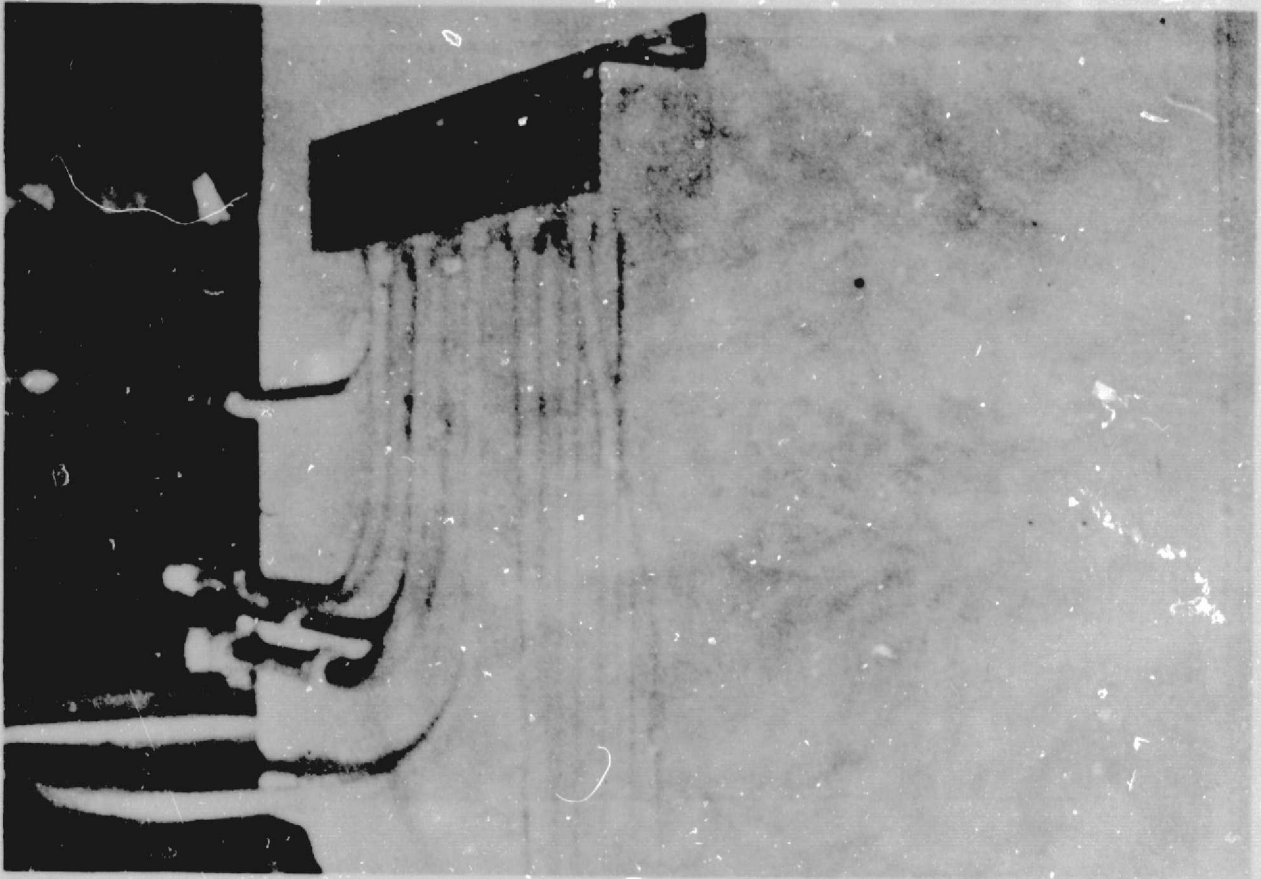


Air Handler Above Ceiling (Very Crowded)

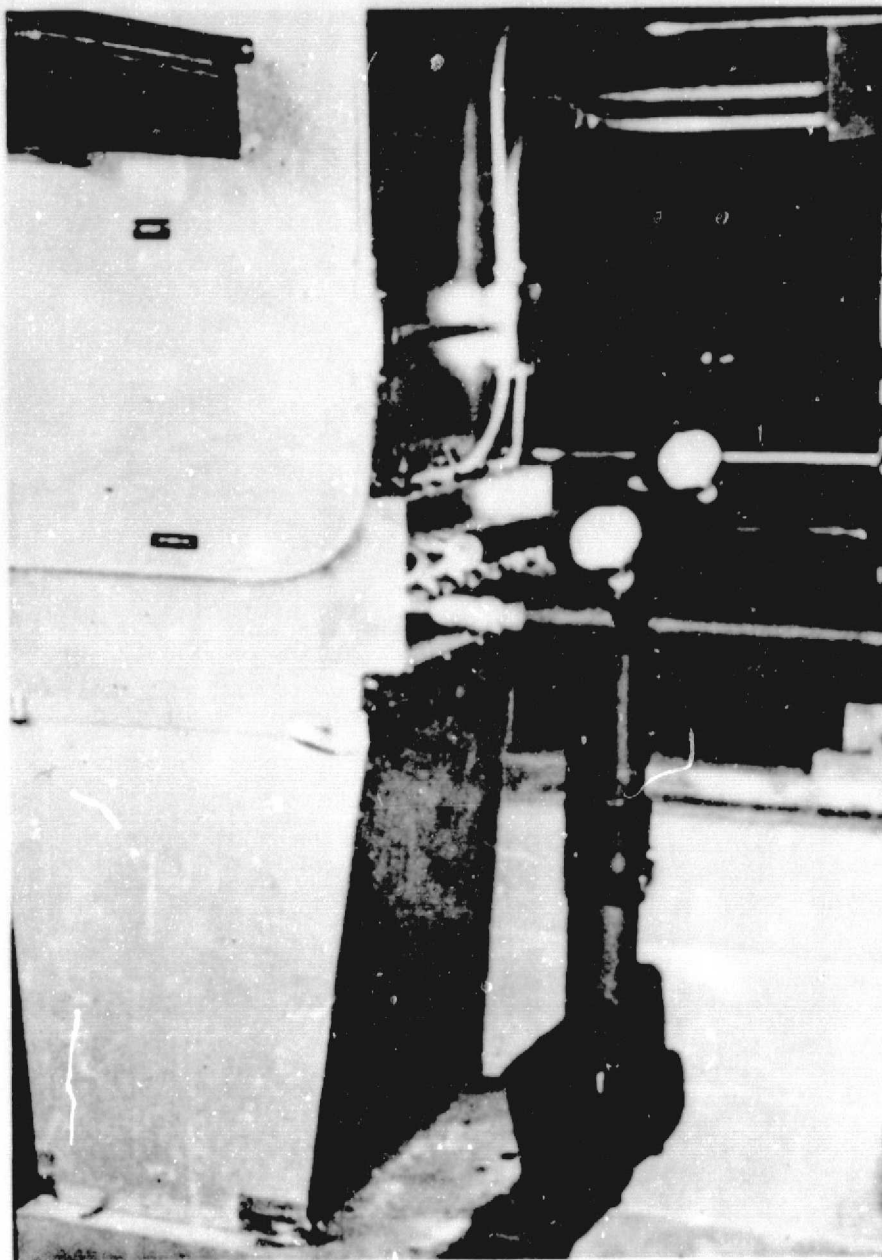


Heat Exchanger on Left - Preheat Domestic
Hot Water Heater in Middle - Gas Water
Heater on Right

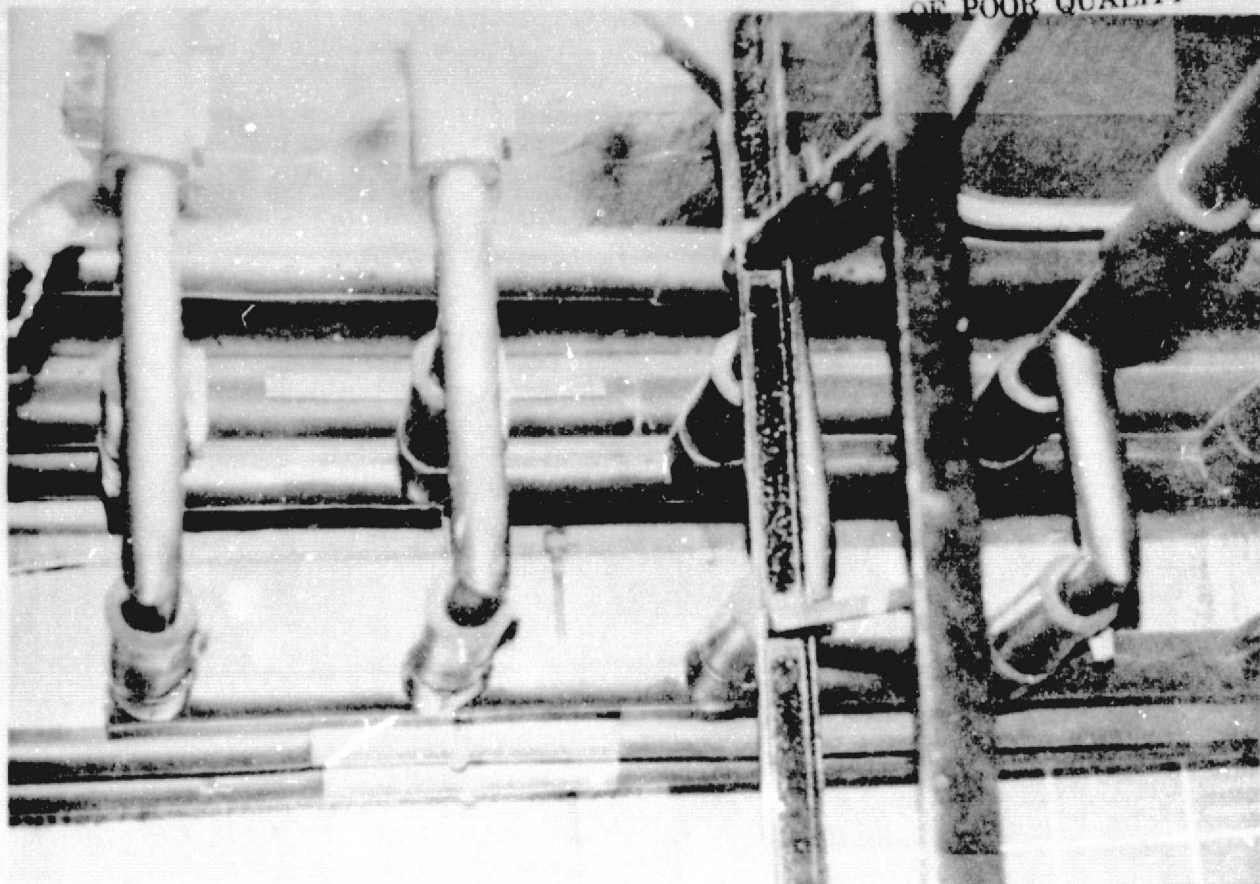
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Conduit Rough-In Trough for Monitor



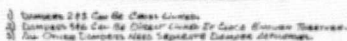
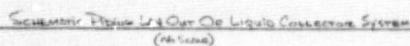
Water Coil Near Center of Picture and
Glycol Coil Near Bottom Serving Perimeter
Air Handler



Glycol Piping from Collectors

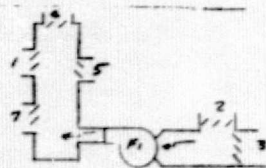


Glycol Piping from Collectors

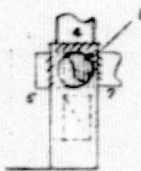
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SCHEMATIC DUCT LAYOUT OF AIR COLLECTION SYSTEM
(Vn School)

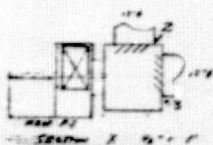
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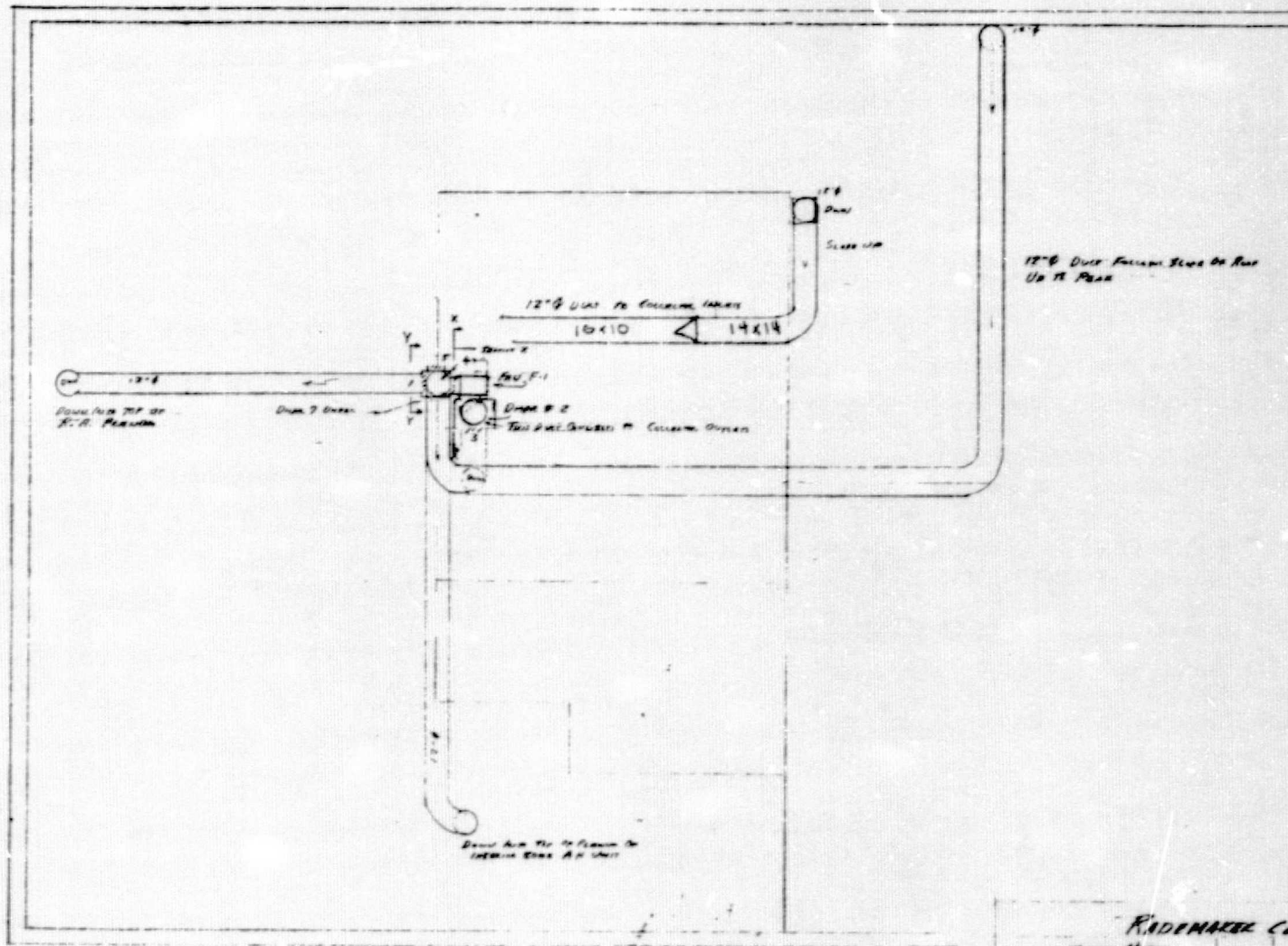
SCHEMATIC OF FLOW #1 AND #2
DRAINAGE PIPING NO SCALE



SECTION 2 1/2" x 1"
RADIUM PIPING



SECTION 2 1/2" x 1"
RADIUM PIPING



SECTION 2 1/2" x 1"
RADIUM PIPING

RADIUM CASE		
SOURCE	NO. 1	NO.
DATE		NO. 241-6

26-241-0

Prothium Corp. N.Y. N.Y.

15/5/90

10

First Row

SECTION II

. CONTROLS

CONTROL LOGIC NARRATIVE

SEQUENCE OF OPERATION FOR SOLAR HEATING SYSTEM, RADENAKER CORPORATION

A. LIQUID COLLECTOR SYSTEM:

When the master liquid collector solar heat switch is placed in the "Automatic" position (Switch S-1), the differential thermostat T-B will allow operation of the glycol pump P-1 through the action of Relay R-PG. R-PG has a 15 second time delay off cycle to prevent fluttering of the glycol pump if the solid state circuit within T-B should flutter momentarily. Radiation sensing thermostat T-BA under the collector panel near the top of a typical collector surface operates with thermostat T-B-B in the storage tank sensing average water temperature of the tank to allow operation of the glycol pump when the radiation temperature is greater than the tank temperature. The domestic hot water solar heat switch, S-2, when placed in the "Automatic" position will allow its pump P-3 to operate at the same time P-1 operates through Relay R-DW. Differential thermostat T-11 has one element T-11-A located on the glycol line leaving the collectors, and its auxiliary element T-11-B is on the bottom of the domestic hot water heater. A high limit safety thermostat T-11-C strapped onto the center of the tank under the insulation of the tank allows Pump P-3 to stop if the temperature should exceed 180° on the tank surface. When relay R-OW is energized, Erie valve V-1 opens to allow glycol to flow through the heat exchanger serving the domestic hot water circuit.

The room thermostat serving the exterior zone designated as T-5 is a two stage heat-one stage cool thermostat. The first stage of heat on this thermostat will energize Relay R-1. When Relay R-1 is energized and providing Switch S-3 is in the "Automatic" position (main office heat from liquid solar system switch), hot water valve V-2 will open to preheat coil after the glycol has already passed through the heat exchanger in the tank. (This serves as an economizer to extract more heat from the collector by increasing the efficiency of the collector.) A thermostat T-4 sensing the return glycol temperature from the hot water heat exchanger will not, however, let this valve open unless the water coming back is above 120°.

The hot water pump P-2 which distributes water in the hot water heating system from the storage tank will be energized at any time Relay RA is energized indicating a demand for heat at either zone and provided that the temperature of the water in the top of the storage tank as sensed by thermostat T-7 is above 85° (indicating that heat is available to be distributed to the hot water coils). A switch on the panel (S-4) allows the drafting room air handling unit to operate from the liquid solar heating system. Thermostat T-10 in the drafting room will open Erie valve V-3 allowing hot water flow through the fan coil unit's coil whenever heat is demanded in the space. At the same time, the fan will be allowed to operate provided that the hot water pump P-2 is running as interlocked through relay RHW. Relay RA will energize also which serves as the interlock relay for Pump P-2. Refer to schematic wiring diagram for interlock circuit detail.

It should be pointed out that a second stage of heat demanded by the room thermostat T-5 at the perimeter office will allow the gas heat to be energized to bring the space up to temperature.

B. AIR COLLECTOR SYSTEM:

The master switch for the air collector solar heat system is marked SA-1. Placing this switch in the "Automatic" position allows the differential thermostat T-1 to cycle Relay R-AF when the solar radiation input as sensed by thermostat TA-1A is greater than the temperature at the bottom of the rock storage box as sensed by TA-1B. Switch SA-2 on the control panel when placed in the "Automatic" position allows the interior office zone to have heat introduced from the air solar system provided its room thermostat is calling for heat which in turn would energize Relay RA-7. Relay RA-7 will open damper #7 and will allow starting of fan F-1 which will introduce heat directly from the solar collector system to the interior zone provided relay R-AF is energized. If not, it will introduce heat from the rock storage stack assuming that thermostat TA-3 indicates a temperature of at least 85° at the top of the rock storage stack. If heat does not exist from either source, fan F-1 will not operate. Switch SA-3 when placed in the "Automatic" position allows heat to enter the main office perimeter zone from the air solar heat system whenever Thermostat T-5 calls for first stage of heat through interlock of a pole of relay R-1. The normally closed contact of relay RA-7 is in series with the circuit to prevent relay RA-1 from energizing if the interior zone thermostat is calling for heat (this gives the interior zone precedence on getting heat from the air collector system). When relay RA-1 is energized, Damper #1 opens.

Switch SA-4 when placed in the "Automatic" position allows heat to be introduced to the warehouse from the air solar heat system providing the room thermostat TA-6 serving the warehouse zone indicates the demand for heat and further provided that RA-7 and RA-8 relays are not energized indicating a demand for heat in either of the office zones. During the "Automatic" operation, the relay RA-5 upon demand of heat for TA-6 will open dampers #5 and #6.

The dampers which control heat selection from rock storage or from collectors are controlled from Relay R-AF. If R-AF is energized indicating the collectors have heat available, damper #2 will be opened and Damper #3 will be closed. If R-AF is not energized, damper #2 will be closed and damper #3 will open to allow heat to come from the rock storage stack. Relay RA-4 will be energized to allow opening of Damper #4 any time the solar collectors have heat available and provided that none of the three zones are demanding heat.

A summer vent switch marked SA-5 with indications for "Automatic-Summer" will allow system to work fully automatically as described above when placed in the "Automatic" position. When placed in the "Summer" position, however, relay RA-8 will be energized allowing heat to vent out the stack to outdoors at the same time Relay RA-5 will be energized allowing dampers #5 and #6 to open which provides a natural draft from the warehouse through the collectors, thereby, keeping the collectors reasonably cool in the summertime.

Pilot lights are provided on the panel to indicate which dampers are opened and to indicate when fan F-1 is running, when each of the three pumps is running, and when the fan serving the drafting room is running.

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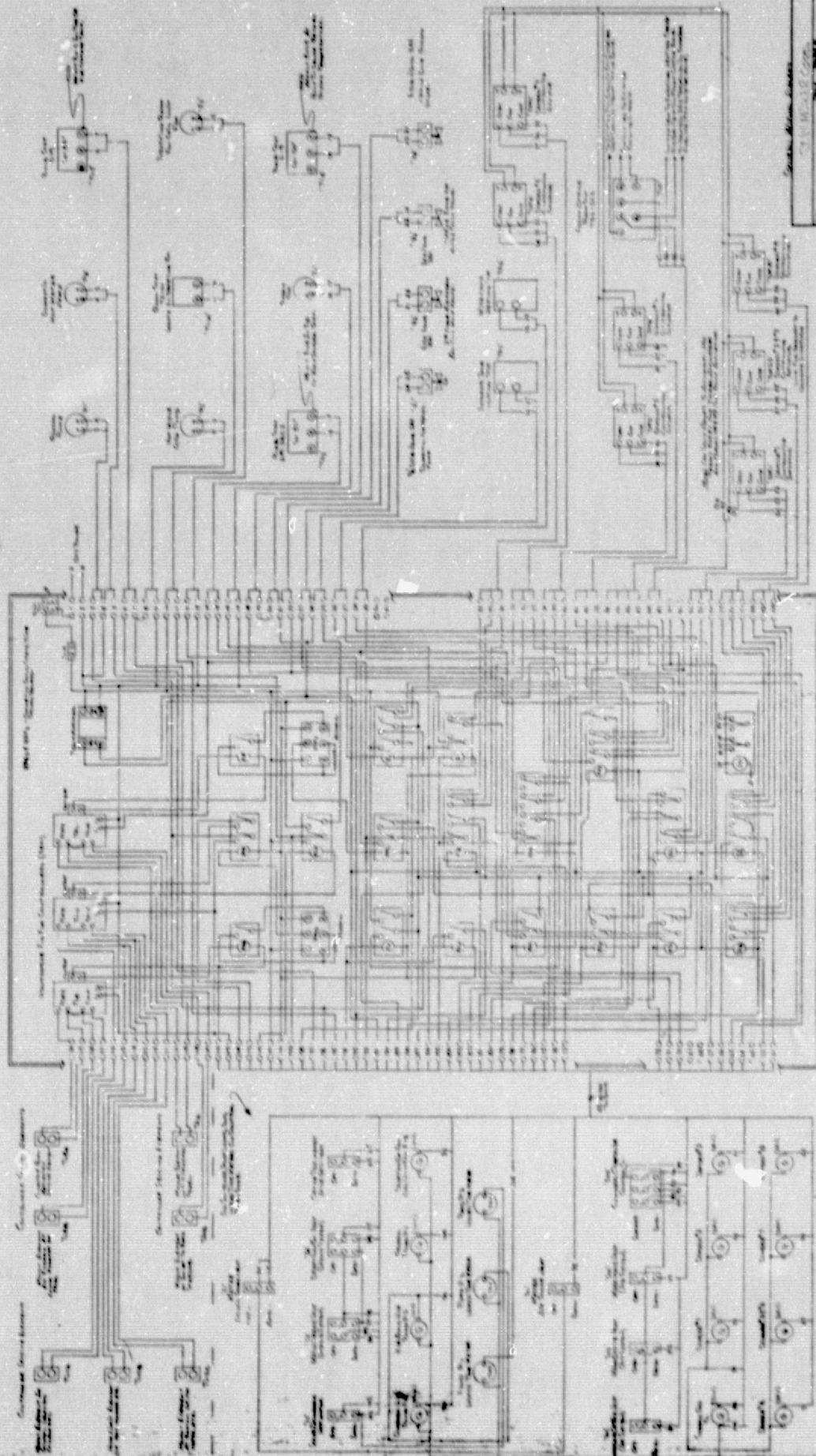
RADENAKER CORP.

CONTROL LOGIC NARRATIVE

DATE: 11/1/61		BY: J. W. RADENAKER		CHECKED: J. W. RADENAKER		APPROVED: J. W. RADENAKER	
PROJECT: SOLAR HEATING SYSTEM		DRAWN BY: J. W. RADENAKER		SCALE: AS SHOWN		SHEET: 1 OF 1	
REVISION: 1		REVISION: 2		REVISION: 3		REVISION: 4	

Transistorized Computer Plate

Rev. 10-15-60



Part No.	Quantity	Description
100-100000	1	Transistorized Computer Plate
100-100001	1	Computer Control Section
100-100002	1	Computer Section
100-100003	1	Power Supply Section
100-100004	1	Control Section

SECTION III

DATA ACQUISITION SYSTEM

DESCRIPTION OF DATA ACQUISITION SYSTEM

In order to obtain information necessary for evaluation of the performance and operation of the solar heating system throughout the year, 47 sensors were installed within the system. These sensors were furnished by the government and installed at government expense in accordance with the document, "SHC-1006, August 4, 1976; Instrumentation Installation Guidelines for the National Solar Heating and Cooling Demonstration Program."

Table 1 schematic reflects the specific location of each of the sensors.

In Table 2, each sensor is described in terms of general location, and the parameter that is being measured. Each sensor is listed by an alpha-numeric code designation. The code designation indicates the following:

Letter Designations

C = Specific Heat	PD = Pressure Differential
D = Direction or Position	Q = Thermal Energy
EE = Electrical Energy	RH = Relative Humidity
EP = Electrical Power	SM = Special Measurement
F = Fuel Flow Rate	T = Temperature
HF = Heat Flow Meter	TD = Differential Temperature
I = Incident Solar Flux (Insolation)	V = Velocity
N = Performance Efficiency or Effectiveness	W = Heat Transport Medium Flow Rate
P = Pressure	TI = Time

Number Sequence

Data Group

001 to 099

climatological

100 to 199

collector

200 to 299

thermal storage

300 to 399

domestic hot water

400 to 499

space heating

500 to 599

space cooling

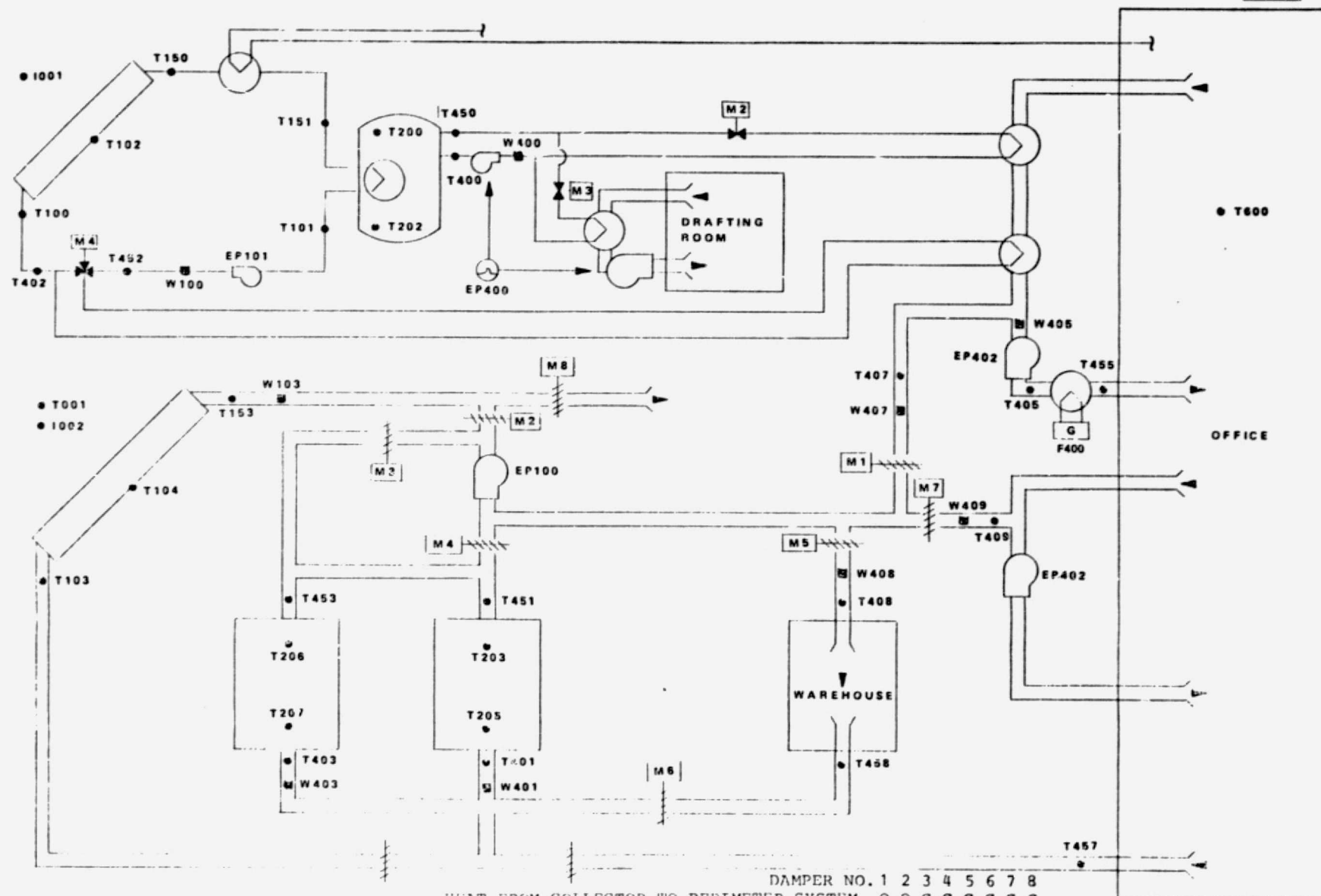
600 to 699

building/load

Each sensor provides data to a Site Data Acquisition Subsystem (SDAS) every 5 minutes around the clock. The SDAS digitizes the data and stores it on tape. Once a day the data is sent by telephone to an IBM facility in Huntsville, Alabama, where it is reduced. Monthly reports are prepared, one of which is sent to Rademaker Corporation.

The monitoring system will permit the government to determine the following kinds of information:

- o Savings in conventional energy resulting from the use of solar energy for heating.
- o Portion of the total heating load supplied by the solar energy.
- o Efficiency of the system in converting solar radiation into useful thermal energy.
- o Thermal performance and reliability of major subsystems or components over the demonstration period.

TABLE 1
SENSOR LOCATION SCHEMATICORIGINAL PAGE IS
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DAMPER NO.	1	2	3	4	5	6	7	8
HEAT FROM COLLECTOR TO PERIMETER SYSTEM	O	O	C	C	C	C	C	C
HEAT FROM COLLECTOR TO ROCK STORAGE	C	O	C	C	C	C	C	C
HEAT FROM STORAGE TO PERIMETER SYSTEM	O	C	O	C	C	C	C	C
HEAT FROM COLLECTOR TO INTERIOR SYSTEM	C	O	C	C	C	C	O	C
HEAT FROM STORAGE TO INTERIOR SYSTEM	C	O	C	O	C	C	O	C
HEAT FROM COLLECTOR TO WAREHOUSE	C	O	C	C	O	O	C	C
HEAT FROM STORAGE TO WAREHOUSE	C	C	O	C	O	O	C	C
SUPPLY VENTING	C	C	O	C	O	C	O	C

TEMPERATURE INSTRUMENTATION REQUIREMENTS															
Measurement															
No	Designation	Number		Justification	Name	S.N	Range (°F)		Pipe Type	Pipe Size (inches)	Tube Size (inches)	Installation Method	Ref Fig No	Thermowell Part No	Probe Part No
		J-Box	SDAS				Min	Max							
1	T001	30		N113	Ambient air dry bulb temp					NA				IS4	S53P85Z36
2	T100	2		Q100	Collector array inlet temp liquid				CU	1				F203U42	S57P72Z36
3	T150	32		Q100	Collector array outlet temp liquid				CU	1/1				F203U42	S53P72Z36
4	T102	34		N116	Collector absorber surface temp liquid										S34A
5	T103	36		Q100	Collector array inlet temp air				Air Duct					F132	S57P85Z36
6	T153	6		Q100	Collector array outlet temp air				Air Duct					F132	S53P85Z36
7	T104	38		N116	Collector absorber surface temp air										S34A
8	T101	4		Q200	Storage tank outlet temp-collector loop				CU	1/1				F203U42	S53P72Z36
9	T450	12		Q201	Storage tank outlet-to-load temp				CU	1-1/4				F203U42	S53P72Z36
10	T400	7		Q201	Storage tank temp load				CU	1-1/4				F203U42	S57P72Z36
11	T200	40		Q202	Storage tank temp - top liquid									F203U154	S53P180Z36
12	T202	42		Q202	Storage tank temp - bottom liquid									F203U154	S53P180Z36
13	T203	43		Q202	Rock storage temp - top									F203U154	S53P180Z36
14	T205	45		Q202	Rock storage temp - bottom									F203U154	S53P180Z36
15	T451	14		Q200/ Q201	Rock storage, inlet-to-outlet differential temp				Air Duct					F132	S53P85Z36
16	T452	16		Q402	Glycol coil, inlet temp				CU	1				F203U42	S53P72Z36
17	T455	20		Q401	Furnace outlet temp air				Air Duct					F132	S53P85Z36
18	T4007	24		Q402	Perimeter air temp				Air Duct					F132	S53P85Z36

TABLE 2

SECTION IV
ACCEPTANCE TEST

ACCEPTANCE TEST PLAN #1

FOR

SOLAR HEATING SYSTEM

RADEMAKER CORPORATION

LOUISVILLE, KENTUCKY

Performed 7/3/78

by

Thomas Empson and Harry Sladen

of

Rademaker Corporation

Check
Column

A. LIQUID COLLECTOR SYSTEM (Refer to Drawings 76-241-2 and 76-241-4)

1. Place the master liquid solar heat switch into the "Automatic" position. Note water temperature below center of tank at point where sensor TL-8B is located. Hawthorne controller TL-8A should allow cycling of the glycol pump, provided collector sensing element is 15° higher than tank sensing element temperature. Check this in early morning prior to the time when collectors are warm and glycol pump should be off. When unit cycles on, note water temperatures entering tank heat exchanger and see if unit cycles off as glycol temperature exceeds tank temperature. If it does, this circuit is not performing satisfactorily.
2. Place the main office heat switch in the "Automatic" position. Raise the setting of the room thermostat in the perimeter zone. The valve serving the water coil for this zone (V2) should open at the same time the hot water circulating pump (P2) should start. Valve V4 in the glycol circuit serving the preheat coil

OK

OK

OK

for the perimeter zone should also open, provided the bulb thermostat TL-4 in the return glycol line is sensing above 125°. If the stat is not causing this valve to open, drop the setting of TL-4 to assure that the electric circuit is functioning correctly and will allow the glycol valve to open when the return glycol temperature is acceptably warm.

OK

3. Place the drafting room unit heating switch in the "Automatic" position. Thermostat T-10 in the Drafting Room, if raised above room temperature, should allow the valve (V-3) to open and pump P-2 to start at the same time. Likewise, the fan should start at the same time, allowing heat from the unit to the Drafting Room.

OK

OK

4. Take the temperature of the water in the domestic hot water storage tank. Preferable check-out should occur when the water tank is approximately room temperature and when the glycol temperature is above 120°. This would then allow the domestic hot water differential control (TL-11) to cycle the domestic hot water pump (P-3) and, at the same time, to open the domestic hot water glycol valve (V-1) to allow introduction of heat to the heat exchanger serving the domestic hot water from the glycol circuit. Observe the temperature of the water in the storage tank and, as it rises above the glycol circuit temperature, it should shut off the glycol valve (V-1) and stop the domestic hot water circulating pump (P-3).

OK

OK

5. Note the Lapse Time Meter for Pumps P-1, P-2, and P-3, and the pilot lights for the three pumps and Drafting Room fan. Note to see if these function at the same time as the respective piece of equipment is energized.

OK

6. Place the office perimeter zone gas heat switch in the "Automatic" position and raise the heating thermostat in the perimeter office zone. This should cause gas heat to come on to supplement the solar heating system. Both solar and gas can work together.

OK

7. Place each of the respective system mode switches in the "Off" position and see if the respective system shuts down accordingly. Follow-up by placing the master liquid solar heat switch to the "Off" position and all respective switches associates with the liquid solar heating system should shut down, including the glycol pump.

OK

OK

B. AIR COLLECTOR SYSTEM

1. Place the master switch SA-1 in the "Automatic" position. This should allow the fan to start if the temperature sensed by the thermostat on the hot air collector (TA-1A) is 20° greater than the temperature at the bottom of the rock storage box, as sensed by TA-1B. Assuming that the respective system switches are all in the "Off" position and the summer override switch is in the "Automatic" position, and provided heat exists at the hot air collector, Damper #4 should be opened and Damper #3 should be opened, with all others being closed. This allows the fan to charge the rock storage with heat from the collectors.

OK

OK

2. Place the interior office heating switch to the "Automatic" position and adjust the thermostat from this zone (TA-2) to call for heat. This should close Damper #4 and open Damper #7 which allows the introduction of heat to the interior zone. See Damper Schedule for ease of determination of respective damper position. This schedule is on Drawing 76-241-2.

OK
ALL PER
SCHEDULE.

3. Reposition the interior office switch to the "Off" position and place the main office heat (perimeter zone) to the "Automatic" position. Raise the setting of the room thermostat serving the perimeter zone (thermostat TL-5). This should allow Damper #1 to open. It should be noted at this point that if the collectors are putting out heat as previously described, Damper #2 will be opened, Damper #3 will be closed under this situation. However, if the collectors are not warm and if the rock storage has heat within it as sensed by Thermostat TA-3, Damper #3 will be opened and Damper #2 will be closed, allowing heat to be introduced from the rock storage. Again, refer to the Damper Schedule and see if the dampers are in the proper position.

OK

OK

OK
ALL PER
SCHEDULE.

4. Now, with all air system switches in the "Off" position (except the warehouse zone), place this one in the "Automatic" position. Damper #5 should open to allow heat to enter the warehouse, provided the room thermostat in the warehouse (TA-6) is calling for heat. Again, check the Damper Schedule to assure that all dampers are assuming their proper position.

ALL PER
SCHEDULE.

It is necessary to check each of the zone operations with the hot air collector in operation during the day and, likewise, during the period when no heat is available in the collectors and heat is already stored in the rock storage. Under each situation, the Damper Schedule should be carefully noted.

ALL OK.

Likewise, the pilot lights should be observed for each respective damper and the fan to determine if the pilot lights are giving a true indication of the operating mode. Also, note the Lapse Time Meter which operates when the fan is in operation to determine the number of hours used correctly.

OK

OK

5. Place the summer override switch in the "Summer" position and check to see if dampers have assumed the positions indicated in the Damper Schedule, namely, that Damper #8 is opened allowing venting by gravity without the fan operation.

OK

6. During the checking of each damper sequence, the exact travel of each of the dampers should be observed to assure that tight shut-off is accomplished and that full opening is accomplished by each respective damper motor. This will prevent overheating of any single zone to the linkage. Also, check temperatures of air being introduced to each respective zone to get a general idea of the output capability of the collectors and/or the rock storage system as relates to that respective zone.

ALL OK
EXCEPT #1
WHICH LEAKS
AROUND PERI-
METER SLIGHT
NEW DAMPER
NEEDED.

OK

7. Generally observe the system to assure that heat is not being dissipated from the system to the outdoors through the collectors.

OK.

This can be noted easily by watching the temperature of the air at the fan discharge when it is drawing from the collectors. If, at any time, the temperature drops below the temperature in the rock storage, which is usually ambient temperature (approximately 70-75°), then the system is dissipating heat instead of collecting it. The probable cause of this would be an inoperative or miscalibrated differential temperature control. A similar check should be made by observing the differential control function for the glycol loop with the reference temperature being the temperature of the water at the lower quarter of the tank. It should be noted that the glycol pump may occasionally stop, whereas the air system will continue to function. The reason for this is that the water storage temperature may have raised to a point where the glycol loop would be dissipating heat instead of absorbing it, whereas it is not likely to happen on the air system because the ambient condition of the rock near the bottom of the rock stack will seldom rise above 75°. This is due to the residual effect of the rock as it absorbs heat at the top of the stack and offers wide gradient between top and bottom, whereas the water temperature tends to be somewhat more even from bottom to top.

*No PROBLEM.**OK.*

ACCEPTANCE TEST PLAN #2FORSOLAR HEATING SYSTEMRADEMAKER CORPORATIONLOUISVILLE, KENTUCKY

This test plan was developed to evaluate the instrumentation in both solar heating systems at the Rademaker Corporation installation. These tests will be coincident with at least two Site Data Acquisition Subsystem (SDAS) scans (640 seconds) to permit the recording of measurements under essentially steady-state conditions.

Time
Accomplished
July 4, 1978

I. Air Collector Solar Energy Heating System Tests

A. Solar energy available at collectors (TA-1A, 1B)

- | | |
|--|-----------|
| 1. De-activate both solar heating systems including air handling unit (AHU) fans as well as all load switches and thermostats. | 8:10 a.m. |
| 2. Activate AHU fan for interior zone (F-4). | 8:20 a.m. |
| 3. Activate AHU fan for perimeter zone (F-3). | 8:30 a.m. |
| 4. Activate air collector solar heating system (SA-1). | 8:40 a.m. |
| 5. Demand heat by warehouse (SA-4, TA-6). | 8:50 a.m. |
| 6. Demand first stage heat by perimeter zone (SA-3, TA-5) | 9:00 a.m. |
| 7. Demand heat by interior zone (SA-2, TA-). | |

B. Solar energy available only in storage (TA-3).

- | | |
|--|-----------|
| 1. De-activate both solar heating systems including air handling unit (AHU) fans as well as all load switches and thermostats. | 9:20 a.m. |
| 2. Activate AHU fan for interior zone (F-4). | 9:30 a.m. |
| 3. Activate AHU fan for perimeter zone (F-3). | 9:40 a.m. |
| 4. Activate air collector solar heating system (SA-1). | 9:50 a.m. |

	Time Accomplished
5. Demand heat by warehouse (SA-4, TA-6).	10:00 a.m.
6. Demand first stage heat by perimeter zone (SA-3, T-5).	10:00 a.m.
7. Demand heat by interior zone (Sa-2, TA-).	10:20 a.m.
C. Solar energy not available.	
1. De-activate both solar heating systems including air handling unit (AHU) fans as well as all load switches and thermostats.	10:30 a.m.
2. Activate AHU fan for interior zone (F-4).	10:40 a.m.
3. Activate AHU fan for perimeter zone (F-3).	10:50 a.m.
4. Activate air collector solar heating system (SA-1).	11:00 a.m.
5. Demand heat by warehouse (SA-4, TA-6).	11:10 a.m.
6. Demand first stage heat by perimeter zone (SA-3, T-5)	11:20 a.m.
7. Demand heat by interior zone (SA-2, TA-).	11:30 a.m.
8. Demand second stage heat by perimeter zone(SA-3, T-5)	

II. Liquid Collector Solar Energy Heating System Tests

A. Solar energy available at collectors (T-8A, 8B).	
1. De-activate both solar heating systems including AHU fans as well as all load switches & thermostats.	11:40 a.m.
2. Activate liquid collector solar heating system and AHU fan for perimeter zone (S-1).	11:50 a.m.
B. Solar energy available only in storage (T-7).	
1. Demand first stage heat by perimeter zone (S-3, T-5).	12:00 p.m.
2. Demand heat by drafting room (S-4, T-10).	12:10 p.m.
C. Solar energy not available.	
1. Demand heat by drafting room.	12:20 p.m.

	<u>Time Accomplished</u>
2. Demand first stage heat by perimeter zone (S-3, T-5)	12:30 p.m.
3. Demand second stage heat by perimeter zone (S-3, T-5).	12:40 p.m.
TEST FINISHED	12:50 p.m.

*Numbers in parentheses refer to designations of switches and thermostats.

IBM 8-23-77

International Business Machines Corporation

150 Sparkman Drive
Huntsville, Alabama 35805
205/837-4000

July 19, 1977

RECEIVED JUL 23 1977

Rademaker Corporation
2400 Watterson Trail
Louisville, Kentucky

RECEIVED JUL 25 1977

Attention: Mr. Richard W. Rademaker

Reference: Our Telecon of July 19, 1977

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Gentlemen:

The fan/pump test we are requesting involves operation of your system in the following states. Each state should be maintained for at least ten (10) minutes and the start time of each test state should be recorded. Also, please record the damper and valve positions appropriate for each state. A desirable mode in which to perform the test would be Mode 1 - "Heat from Collector to Perimeter System"

Done 8-23-77

State 1

V-1, 3 & 4
Closed

P1 (Collector Loop Pump) - ON } START 3:45 EDT
F1 (Collector Loop Fan) - ON } STOP 3:55 EDT

DM# 244
STATE 1-2 3 & 4

DM# 35641
STATE 5

State 2

V-3 OPEN

P1 and P2 (Load Loop Pump) - ON } 3:55 START EDT
F1 and F2 (Draught Area Fan Coil) - ON } 4:05 STOP EDT

State 3

V-1 & 3 OPEN

P1, P2 and P3 (DHW Loop Pump) - ON } 4:08 START EDT
F1, F2 and F3 (Perimeter AH Fan) - ON } 4:20 STOP EDT

State 4

V-1 OPEN

P3 only (DHW Loop Pump) - ON } 4:25 START EDT
F1, F2, F3 and F4 (Interior AH Fan) - ON } 4:35 STOP EDT

State 5

All Closed

F3 & F4, both - ON (note which applies) } 4:38 START EDT
No Pumps Running } 4:48 STOP EDT

NOTE: THE MIDDLE 5 MIN. PERIOD OF EACH STATE
SHOULD GIVE ACCURATE READINGS.

SECTION V

INTERIM PERFORMANCE CRITERIA CERTIFICATION

RADEMAKER
CORPORATION
2400 WATTERSON TRAIL
BLUEGRASS INDUSTRIAL PARK
LOUISVILLE, KY. 40299
(502) - 267-9438

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August 27, 1975

National Aeronautics & Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Attention: Mr. Thomas Davidson, FA33

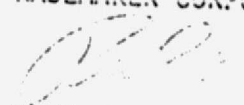
Subject: Contract E (49-18) 2335

Gentlemen:

This will acknowledge your letter of August 10. Consider this letter as our letter of certification that our solar system meets the Interim Performance Criteria where applicable.

Yours very truly,

RADEMAKER CORPORATION


R. W. Rademaker
President

RWR/b

INTERIM PERFORMANCE CRITERIA

CERTIFICATION

DEMONSTRATION CONTRACTOR Rademaker Corporation

SYSTEM LOCATION Louisville, Kentucky

SYSTEM TYPE Space Heating and Domestic Hot Water Heating

CERTIFIED BY *[Signature]*
Authorized Representative
R. W. Rademaker

DATE August 26, 1976

SECTION VI

UPDATED KEY INFORMATION FROM ORIGINAL PROPOSAL

UPDATED KEY INFORMATION FROM ORIGINAL PROPOSAL

One of the primary aims of the installation was to determine the comparative results of the air system versus the liquid system operating under a similar environment. Since the system has currently been operating through two winters, a considerable amount of information has become available to the writer as a result of observation even without detailed information from the monitoring system. First of all, there is relatively little difference in the apparent performance of the air system and the liquid system due to their variation in tilt angle. It appears that the air system responds more readily to the diffuse radiation situation which is partly because it is oriented more flatly and, secondarily, because it is operating with respect to a lower reference temperature.

Experiments have been conducted using a reflector on one of the collectors which is very easy to see on the photographs accompanying this presentation. It is apparent that during clear days (heavy direct insolation), the reflector has a significant added benefit during summer cycle of operation with temperatures being as much as 20° higher with the same flow. The system was installed with separate circuits from each respective collector so that results such as this could be easily obtained.

It was thought when the system was designed that the glycol preheat coil would serve considerable value for extracting the maximum heat from the liquid system. In actual practice, however, it is observed that the heat from the glycol is extracted within the tank due to the fact that the demands upon the system are always heavy with respect to the insolation. In other words, the heat is being demanded as fast as it can be absorbed by the collectors. The temperature of the glycol relatively always stays below the 120° temperature which was set as the point at which glycol could pass through the preheat coil prior to reentering the collector loop. When it is allowed to enter this preheat coil at a lower temperature, it drops the whole temperature threshold of the storage and thereby merits nothing to the system.

It should further be noted that additional surface was added to the heat exchanger within the storage tank after the system had been placed in operation the first year since it was obvious that heat transfer was not sufficient during static conditions.

SECTION VII

MAJOR MAINTENANCE AND CONSTRUCTION PROBLEMS ENCOUNTERED AND RECOMMENDATIONS

MAJOR MAINTENANCE AND CONSTRUCTION PROBLEMS ENCOUNTERED AND RECOMMENDATIONS

Generally, there were some problems encountered and they are listed herein.

1. Glazing Problem

The Kalwall applied to the SDI collectors degraded rather heavily during the first summer and winter. It was replaced in the early summer of 1977 and went through the second winter with considerable improvement. Apparently, the Kalwall Premium II is better than the original Kalwall. Likewise, the glazing on the Solaron collectors showed a white deposit between the layers of glass after the first winter of operation. This glazing was replaced in 9 of the 10 panels at the same time the above mentioned glazing was replaced. The new glazing appears to have less of a problem, however, some evidence of white deposits has reoccurred after about 14 months. The condensation between the layers of glass has not been eliminated. The writer has concluded that it is very nearly impossible to eliminate this problem, no matter how carefully the instructions of the manufacturer are followed.

2. Insulation

The Armaflex insulation used on the outside of the building tended to stiffen up and show considerable degrading during the first summer and winter. During the summer of 1977, the Armaflex was covered with a fiberglass insulation and then the complete insulation package was covered with a plastic material and sealed at all joints. Likewise, cans were placed over the edges of the insulation to assure that no water could get through to reduce the value of the insulation. The net result was considerable gain during the next winter's operation. The recommendation of the writer would be not to use Armaflex outdoors. It works quite satisfactorily indoors. The manufacturer's paint applied to that which was outdoors did not appear to make much difference. The degrading still occurred.

3. Controls

Problems occurred with the differential temperature control devices which are manufactured by Hawthorne. The units originally installed tended to stutter upon start-up and shut-down causing the fans and pumps respectively to chatter at start-up and shut-down. This was solved by the introduction of time-delay relays in the circuits. Likewise, the manufacturer sent replacement units which still seemed to have the same problem occasionally. Time-delay relays are recommended to eliminate this occurrence.

4. Glycol

A freeze-up with 20% glycol solution used temporarily during the first winter proved to be evidence that it is desirable to use a greater percentage of glycol. 40% glycol solution is recommended for this part of the country. The problem did not occur due to pipes bursting as a result of freezing, but, instead, failure of the liquid to flow through the pipes even though the sun had increased the temperature of the liquid at the collectors to the point

2 -

4. Glycol (continued)

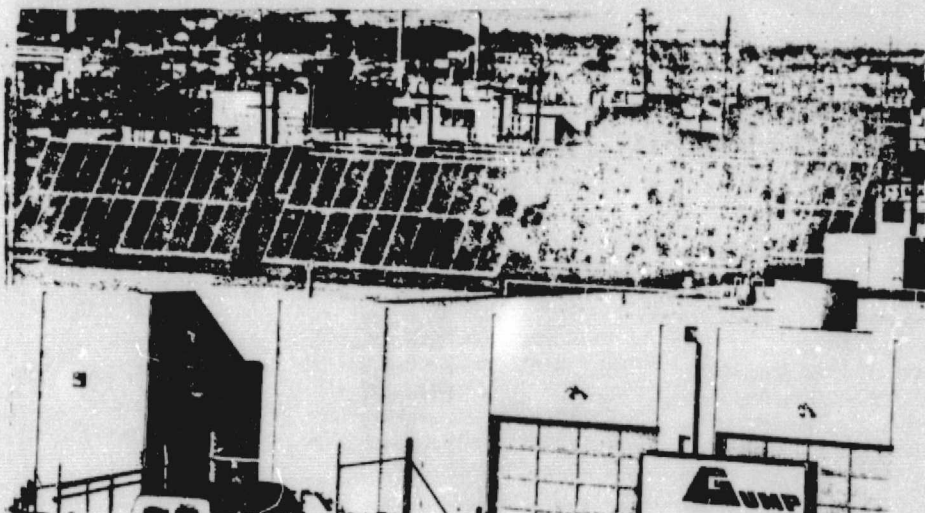
where it would melt below the slush point. Failure of the liquid to flow caused glycol to be ejected through a gasket in one of the motorized valves due to increased pressure when the relief valve was isolated due to the presence of slush. No problem has occurred with respect to this since the 40% glycol was installed prior to the second winter.

5. Maintenance

Practically no maintenance problems have occurred with either of the systems other than those items outlined above. Generally, the air system is shut down during the summertime since the slight leakage of the dampers entering each of the two air handling systems causes an added load to the air conditioning system. This leakage does not seem to be a problem during the winter, however, the writer does intend to replace the damper #1 serving the outer zone since that leakage is more evident and the use of a tighter seal damper will make the job a better one.

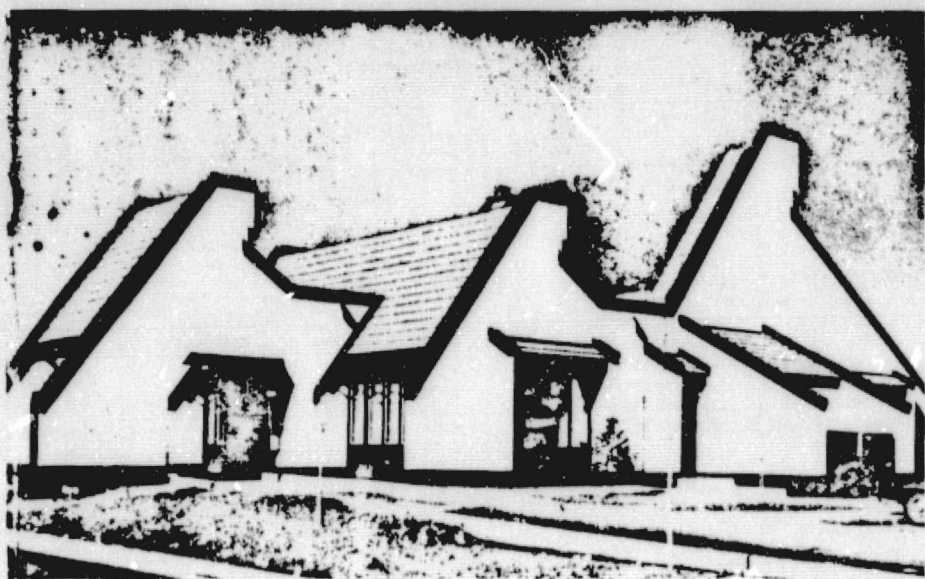
SECTION VIII

OPERATION AND MAINTENANCE MANUAL



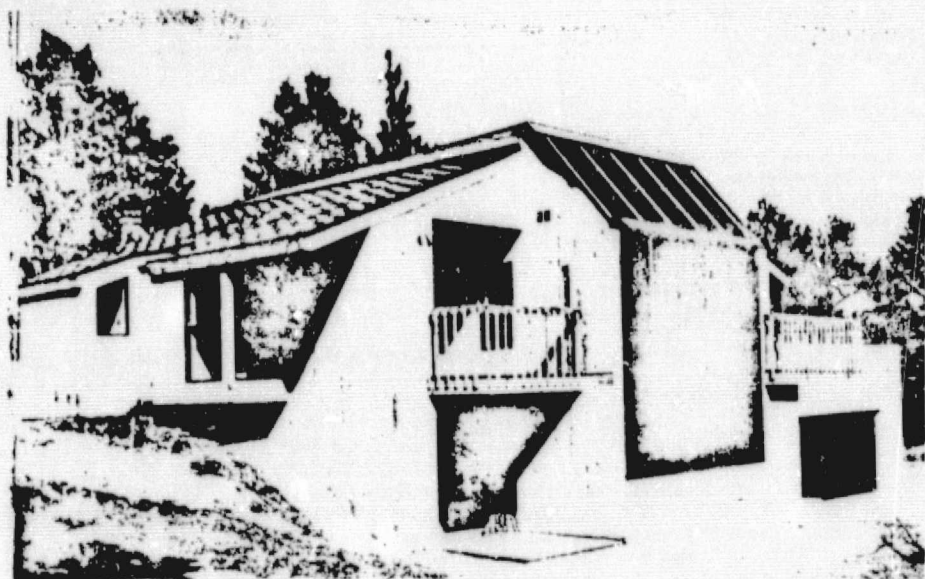
Space Heating / Domestic Water Heating
Make-Up Air Heating / Process Water Heating

Architect: Intergroup Architects



Space Heating / Domestic Water Heating
Ventilation Air Heating

Architect: Ames and Thorpe



Forced Air Space Heating / Pool Water Heating
Domestic Water Heating

Architect: Crowther Solar Group

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SOLARON CORPORATION

Solar AIR heating systems produce more usable energy than liquid solar systems. An independent test of side by side air and liquid solar systems at Colorado State University states: "... the air system operated 45 percent longer during the day than the liquid system and collected 38 percent more heat." "This is a consequence of stratified heat storage in the pebble bed for the air system and nearly uniform temperature in the water storage tank of the liquid system." This is described in terms of the solar system performance equation on page four of its brochure.

The SOLARON AIR COLLECTOR offers the following advantages:

- 10 Year performance warranty.
- Safe, reliable and virtually maintenance-free operation.
- Freedom from damage by freezing or boiling.
- Absence of pipes which can corrode and leak.
- Requires no antifreeze or stagnation pressure relief controls.
- Approved by HUD and ERDA for Federally funded projects.

MR—MANUFACTURER

Solaron's business is the practical application of solar energy. We design, manufacture and market solar heating systems for industrial, commercial, agricultural process drying and residential buildings. The heart of our system is the air-type solar collector, a design based on over 30 years research and development by Dr. George Lof. To contact the nearest Solaron dealer, call the SWEETS BUYLINE.

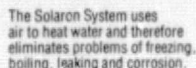
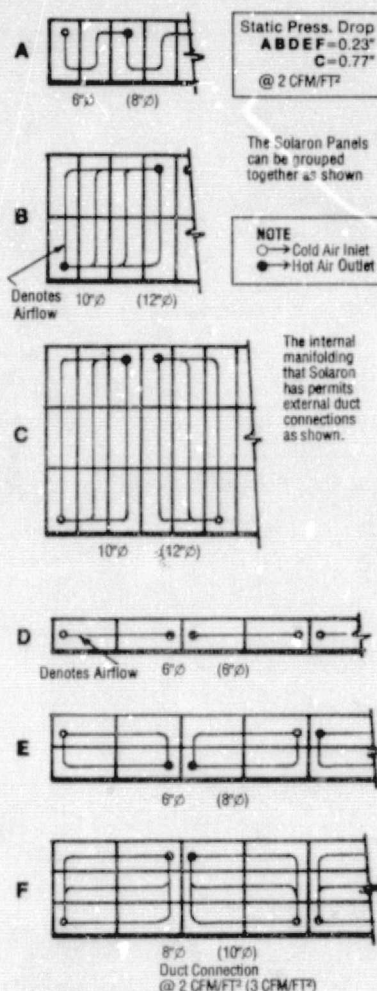
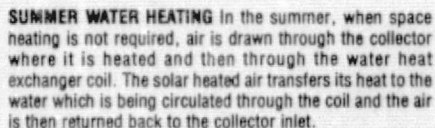
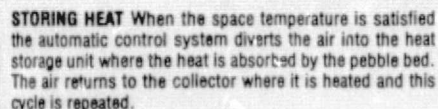
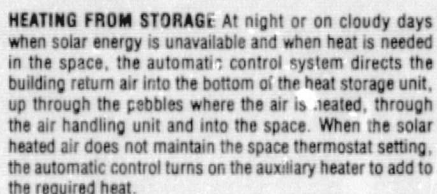
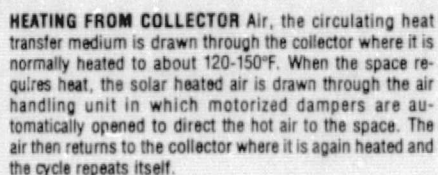
Design Assistance: Solaron has a complete design manual covering all aspects of solar system engineering, architectural requirements and economics. Contact Solaron for a copy of the design manual. Experienced and technical personnel are available to assist on any special applications.



Solaron in all aspects of solar heating, design, equipment application and installation. Solaron engineers and field servicemen support the distributors and dealers as required, and provide on site assistance.

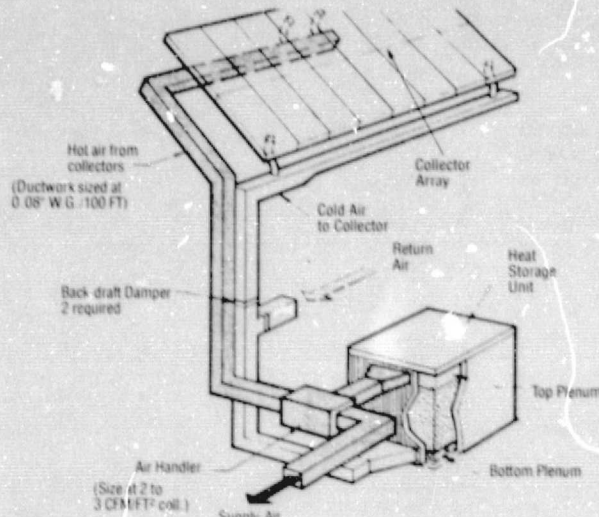
The Solaron collector, air handler and controller and necessary ductwork is installed by the HVAC contractor. The general contractor usually builds the heat storage container. The system is then tested through all of the operating modes and thoroughly checked for proper operation.

TYPICAL COLLECTOR ARRAYS

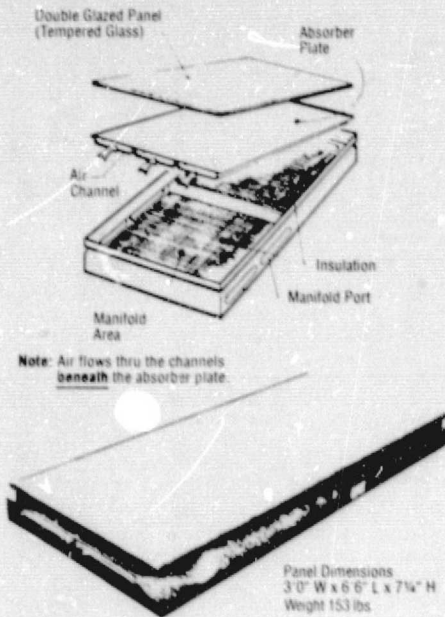


The Solaron Domestic Water Heater System involves a very simple operating cycle. Solar energy is collected by the south facing collector **1**. Air is circulated by the heat exchange unit **2** where the solar energy is transferred to the water being circulated by the domestic water circulating pump **5**. Solar heated water is continuously circulated into the storage tank **3** as long as the Solaron control unit indicates that solar energy is available at the collectors **1** and until tank temperature in the storage tank **3** reaches 160 degrees F. When hot water is required water is drawn from the conventional domestic hot water heater **4** and preheated water is drawn from the storage tank **3** into the conventional domestic water heater.

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CP—COMPONENTS, PARTS



LS (patents applied for)

The Solaron solar collector is an advanced type of an air heating, flat plate collector. Our exclusive internal manifolding allows the Solaron collector to be completely modular. Factory preassembled collector panels are plugged into each other with a minimum of installation time. Air inlets and outlets are field cut into each collector array as required. The Solaron solar collector is designed for installation on any structurally sound surface, such as a roof, wall or specially made supports.

The Solaron solar collector has the following general construction characteristics:

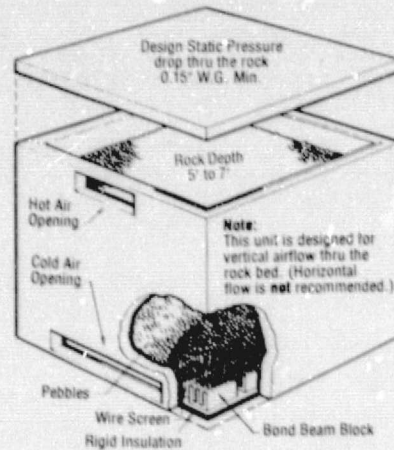
Absorber: 28 gauge steel with porcelain enamel coating.

Glazing: Two 1/8" sealed special low iron tempered glass panels with a long life EPDM perimeter gasket. Glass plate can be easily removed for service or replacement.

Pan: 20 gauge steel, fully insulated with 3/4" fiberglass batt. Painted external surfaces.

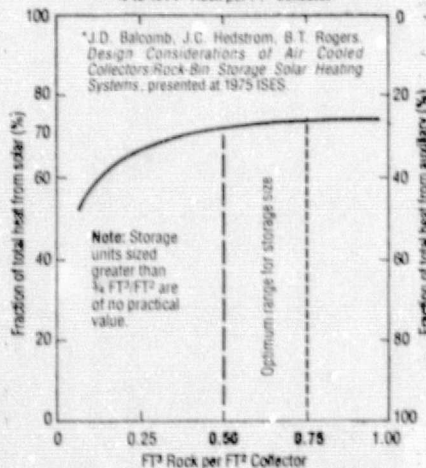
Connection Ports: Unique flange configuration permits tight air seal automatically as modules are installed.

Cap Strip: Painted steel designed to provide weather seal between panels.



The use of pebbles in the heat storage unit is particularly effective with an air circulating solar heating system. The pebble bed maintains a steep temperature stratification (i.e. hot on top and cold on the bottom). This allows air to be provided at the highest available temperature to the heated space from the top of the pebble bed. It also allows air to return from the bottom of the bed to the collector at essentially room temperature. This ensures maximum efficiency of solar heat collection and delivery.

OPTIMUM STORAGE SIZE: 1/2 to 1/4 FT³ Rock per FT² Collector

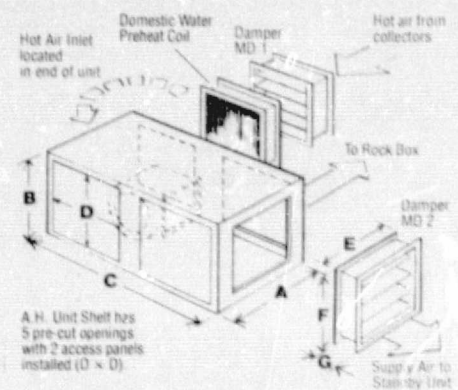


The heat storage unit must be built and installed by the local contractor to Solaron standard drawings and specifications. Contact Solaron for a copy of these specs.

A drawing of a typical installation is shown to the left. The collectors can be grouped as shown or in any of the configurations shown on page 2. Typical Collector Arrays. Due to the Solaron internal manifolding technique (i.e. air flow from one panel to another internally) the external duct connections are minimized as shown above (i.e. one inlet and one outlet for 8 panels, 156 ft.²). This technique reduces field labor and leads to an economical installation.

CONTACT SOLARON TO OBTAIN SYSTEM SCHEMATICS SHOWING HOW TO COMBINE SOLAR HEATING WITH:

- Heating & air conditioning
- Heat pumps
- V.A.V. systems
- Multiple zones
- Process water heating
- Make-up air heating
- Process air htg.-drying
- Swim pool water htg.
- Industrial & agricultural heating



Model No	Air Handling Unit (in.)				Dampers & Coils			C.F.M. Range at 1" S.P.
	A	B	C	D	E	F	G	
AU-0400	20	18	42	14	16	16	8	300 to 1400
AU-0500	24	22	51	18	20	20	10	1200 to 2400

Larger, custom built air handlers are also available.

AIR HANDLING UNIT

Solaron provides a standard factory preassembled air handling unit, including a blower, and motor driven dampers. A separate damper pair is furnished for mounting in the duct system, (i.e. backdraft dampers).

A typical installation for the air handling unit, near the auxiliary heater and heat storage, is shown in the General System Description (upper left). The air handler can be mounted either vertically or horizontally, and with proper orientation and clearance to receive all connecting ducts without interference.

SOLARON AUTOMATIC CONTROLLER

The automatic temperature control unit is included as part of the Solaron system. The controller handles all of the operational modes which are shown in the schematics on page 2. The controller operates the solar side of the system and ties into a 2-stage thermostat to provide solar and/or auxiliary heat to the space as required. The standard controller can be modified (with Solaron hardware) to combine with heat pumps or other types of auxiliary heating systems. Solaron can provide technical assistance to design special controllers for large projects or special applications.

Comparison of various types of solar heating systems can only be done properly if the entire solar system is evaluated over an entire heating season. Collector efficiency is an instantaneous point in time measurement and is not a valid parameter to evaluate the solar system performance. The ideal situation for a solar system is to keep the fluid inlet temperature to the collector as low as possible and have a high usable temperature for space heating. Therefore, the ideal solar system has heat stratified in the storage unit. An air solar system using rocks as the thermal storage provides this stratification. Therefore, the inlet temperature to an air collector is typically 70°F where the liquid collector inlet temperature is 130°F.

$$\frac{Q_{\text{net}}}{A_c} = F_R [H_t \tau \alpha - U_L (T_i - T_a)] = \frac{\text{BTU}}{\text{ft}^2 \text{ Day}}$$

gains losses

Two collectors of similar construction can be compared using the performance equation. When the average collector inlet temperature (T_i) is used, the liquid systems produce almost the same heat output as the air system.

$$\text{AIR } \frac{Q_{\text{net}}}{A_c} = 0.69[(300)(0.75) - (0.8)(70^\circ - 40^\circ)] = 139 \frac{\text{BTU}}{\text{ft}^2 \text{ Day}}$$

$$\text{LIQUID } \frac{Q_{\text{net}}}{A_c} = 0.90[(300)(0.75) - (0.8)(130^\circ - 40^\circ)] = 138 \frac{\text{BTU}}{\text{ft}^2 \text{ Day}}$$

However, this is still an instantaneous point in time measurement which doesn't take into account the fact that the air system will typically collect for longer periods of time and therefore deliver more total heat output. When these systems are evaluated over an entire season, the results are as reported by the C.S.U. report #C00-2868-1. . . . Because of the stratification, the temperature of the air returning to the collector from the bottom of storage is always near room temperature. Thus, the air collector can deliver useful heat from early morning to late afternoon; the liquid system starts up later in the morning and shuts off earlier in the afternoon. . . . Therefore, when system performance is evaluated over an entire season it shows that AIR solar systems actually produce more usable energy than liquid systems. The C.S.U. tests report that the air solar system delivered considerably more heat output than the same sized liquid system right next to it.

*Ref. Hotel, H.C. and Woertz, B.B. A.S.M.E. Transactions 64, 91 1942 Performance of Flat Plate Solar Heat Collectors.

1. Solar Collector Area. The collector area can be determined by using the Solaron Conversion Factors shown to the right. The design heat loss is divided by the S.C.F. to get ft² of collector. Recommendations—Annual fuel savings for space heating should equal 30% to 70%. Annual fuel savings for applications with a more uniform load throughout the year can be higher than 70%.
2. Air Flow Rate. 2 SCFM to 3 SCFM per ft² of solar collector area. Contact Solaron for special applications such as make-up air heating, outside air heating for drying or industrial or agricultural process heating.
3. Heat Storage Size. $\frac{1}{2}$ to $\frac{3}{4}$ ft³ rock per ft² of solar collector area. Rock size $\frac{3}{4}$ " to 1 $\frac{1}{2}$ " diameter.

SELECTION EXAMPLE

Given that: A commercial building with a design heat loss = 136,800 BTU/HR, the location is Denver, Colorado and the desired annual fuel savings is 50%.

1. Collector Area = (Design heat loss) \div (S.C.F.)
136,800 \div (171) = 800 ft² collector.
2. FLOW Rate = (2 SCFM per ft²) \times (Collector Area)
(2) \times (800) = 1600 SCFM
3. Heat Storage Unit = ($\frac{1}{2}$ ft³ rock per ft²) \times (Collector Area)
($\frac{1}{2}$) \times (800) = 400 ft³ rock.

Example: Project at 40° N. Latitude, 500 ft² Collector Area.

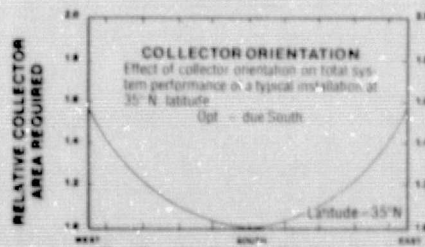
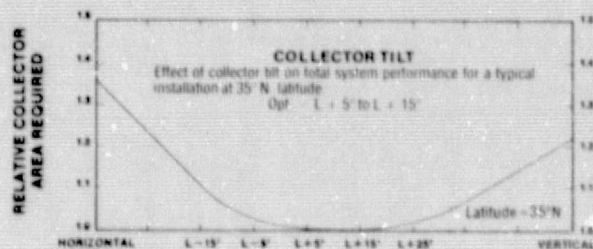
1. If Orientation is 20° to the West. The relative collector area required to provide the same annual fuel savings as a system at due South is approximately 1.04 times the calculated collector area (1.04) \times (500) = 520 ft².
2. The optimum collector tilt would be 45° to 55° (i.e. L \div 5 to L \div 15).
If the collectors were at a tilt of 35° (i.e. L \div 5) the relative collector area required would be 1.03 \times 500 ft² = 515 ft². If both conditions exist (i.e. 20° West & 35° tilt) the correction would be (1.04) (1.03) (500) = 535.6 ft².

$$\text{Solar collector area} = (\text{design heat loss } \frac{\text{BTU}}{\text{HR}}) \div (\text{S.C.F.}) = \text{ft}^2$$

Location	Design S.T.	Fuel Savings/yr		
		30%	50%	70%
Az. Phoenix	45°	556	293	177
Ar. Little Rock	55°	732	112	68
Ca. Davis	40°	240	113	60
Los Angeles	30°	421	216	130
San Francisco	33°	258	127	70
Co. Denver	70°	315	171	104
Fl. Gainesville	38°	458	247	153
Ga. Atlanta	55°	297	150	86
Id. Boise	60°	205	99	52
Il. Lemont	70°	167	83	47
In. Indianapolis	64°	154	71	40
Ia. Ames	77°	195	97	56
Ks. Dodge City	63°	394	158	96
Ky. Lexington	60°	222	106	60
La. New Orleans	35°	267	139	84
Me. Portland	70°	191	97	55
Md. Silver Hill	55°	191	97	55
Ma. Boston	70°	157	80	42
Mi. East Lansing	70°	119	54	29
Mn. St. Cloud	95°	187	108	63
Mo. Columbia	70°	240	114	60
Mt. Great Falls	86°	265	129	74
Ne. Lincoln	70°	225	110	65
Nv. Las Vegas	50°	433	216	135
N.J. Seabrook	55°	160	74	45
N.M. Albuquerque	60°	387	209	124
N.Y. Albany	70°	160	80	50
N.Y.C.	55°	138	67	39
N.C. Raleigh	55°	283	141	87
N.D. Bismark	89°	226	111	63
Oh. Cleveland	63°	127	58	29
Columbus	63°	141	67	35
Ok. Oklahoma City	60°	319	159	96
Or. Medford	55°	171	80	54
Pa. State College	64°	140	66	35
R.I. Newport	59°	169	87	50
S.C. Charleston	40°	313	160	101
S.D. Rapid City	76°	266	137	81
Tn. Nashville	60°	215	103	60
Tx. Ft. Worth	50°	350	194	118
Midland	75°	416	211	126
Ut. Salt Lake City	70°	237	120	63
Va. Mt. Weather	60°	177	90	51
Wa. Seattle	55°	168	82	47
Spokane	70°	170	85	50
Washington D.C.	51°	149	80	44
Wi. Madison	80°	142	72	38
Wy. Lander	82°	329	171	105
Montreal	80°	119	56	27
Toronto	70°	127	59	32


Note collector tilt = 53°

Heating and Air Conditioning Systems Installation Standards for One and Two Family Dwellings and Multifamily Housing including Solar—The Better Heating & Cooling Bureau, S.M.A.C.N.A. Third Edition, Feb. 1977. Reprinted by permission.



(J.D. Balcomb, J.C. Hedstrom, B.T. Rogers, "Design Considerations of Air Cooled Collector/Rock-Bin Storage Solar Heating Systems," presented at 1975 ISES Los Angeles Meeting, Aug. 1975.)

SOLARON CORPORATION
300 GALLERIA TOWER
720 SOUTH COLORADO BLVD.
DENVER, CO 80222
(303) 759-0101



For information on the Solaron Collector Panel Details contact
Solaron Corporation, 300 Galleria Tower-South, 720 S. Colorado
Blvd, Denver, CO 80222.

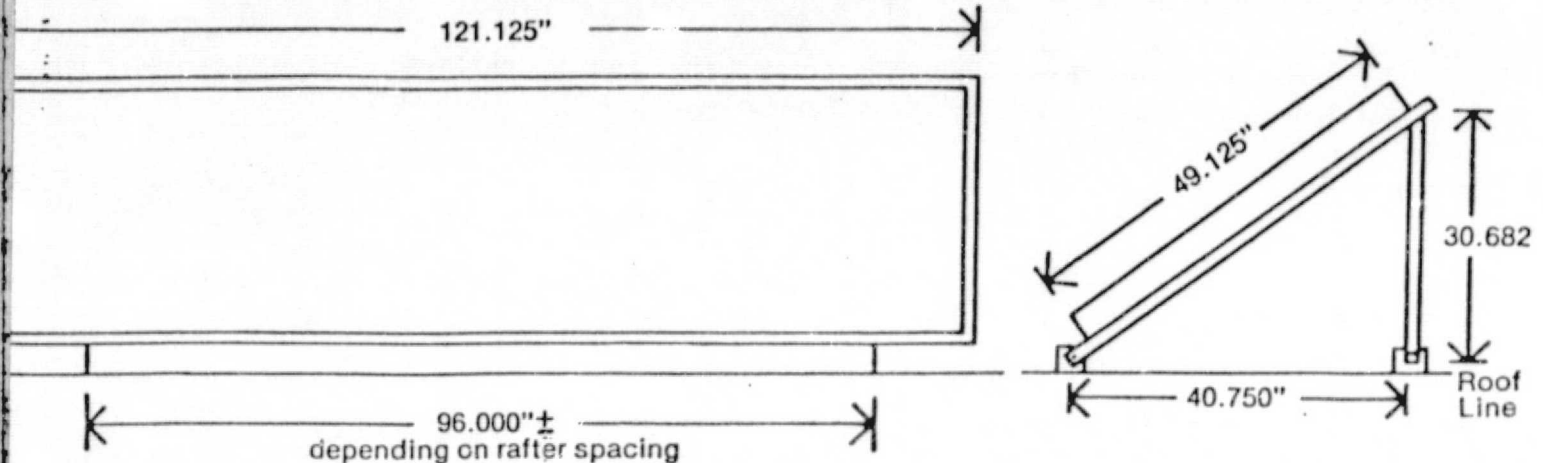


SOLAR DEVELOPMENT INC.

4180 WESTROADS DRIVE WEST PALM BEACH, FLORIDA 33407 TEL. 842-8935

SD5 Solar Collector

Shown for flat roof installation in South Florida. Sloping roofs accommodated by adjusting rear strut length.



TECHNICAL SPECIFICATIONS

USES-water heating, space heating, and pool heating
 DIMENSIONS - 4' x 10' nominal
 WEIGHT - 140 lbs. including roof mounting hardware, 150 lbs. wet
 COLLECTOR PLATE-.012" thick copper
 PIPING - 100 ft. of 1/2" copper 4 3/4" on centers, sinusoidal layout, parallel arrangement available by special order
 PIPE/PLATE CONNECTION - collector-plate grooved to accept 1/2 of pipe circumference for excellent heat transfer, 100% capillary flow solder bond.
 BOX - extruded aluminum sides, .032" aluminum sheet backing
 INSULATION -1" polyurethane (closed cell) or technifoam isocyanurate
 GLAZING - .040" Kalwall Sun-lite Premium, For double glazed northern unit, inner glazing .025" Kalwall Sun-lite Premium, outer .040"
 WIND LOADING - designed for 30 lbs./sq. ft.
 VARIATIONS - collector can be manufactured in various lengths, widths, etc. to meet specific requirements
 PERFORMANCE - the SDI collector has been tested by Desert Sunshine Exposure Tests, Inc., Black Canyon Stage, Arizona using The National Bureau of Standards' Test Procedure. SDI has a computer program to predict performance under various conditions based on the results of this testing. Large installations can be designed optimizing tank size and number of collectors.

PUMP & CONTROLLER - for residential domestic water-use, pump, controller and check valve are mounted in one package. The controller uses two low voltage sensors to compare tank temperature to collector temperature and instructs the pump to circulate only when energy can be added to the system.

PUMP - March 809, 115 VAC or Teel 1P760

FLOW - 3/4 to 1 g.p.m. depending on piping run. Pumps drawing up to 2 amps at 115 VAC may be substituted for multiple collectorsystems

CONTROLLER FEATURES -

1. All solid-state industrial grade construction.
2. Custom aluminum enclosure with "irridited" and sealed finish.
3. Control box may be operated reliably from freezing to over 120 degrees Fahrenheit.
4. Thermistor sensors will operate from 50 degrees below zero to 300 degrees above zero, Fahrenheit.
5. Sensors isolated from high voltage... safe 9 volt signal... no conduit or electrician required.
6. One year guarantee.
7. Operating cost less than one cent per 10 hour day, including pump.

Pricing* (F.O.B. West Palm Beach)

Solar Collector with Roof Mounting Hardware
 single glazed -
 double glazed

Solar Water Heating System
 (same as above plus pump, controller and check valve)
 single glazed -
 double glazed -

* in the absence of a quotation, prices subject to change without notice.

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SOLAR COLLECTOR TEST REPORT

Solar Collector
Test Report

Model: SD5 "Standard"

Solar Development, Inc.
4180 Westroads Drive
West Palm Beach, FL 33407

FLORIDA SOLAR ENERGY CENTER
RESEARCH DEVELOPMENT AND
DEMONSTRATION DIVISION
300 STATE ROAD 401
CAPE CANAVERAL, FLORIDA 32920

RD & D
Test Report
77078



SUMMARY INFORMATION SHEET

FLORIDA SOLAR ENERGY CENTER

300 STATE ROAD 401, CAPE CANAVERAL, FLORIDA 32920, (305) 783-0300



FSEC #77078

MANUFACTURER

Solar Development, Inc.
4180 Westroads Drive
West Palm Beach, FL 33407

Collector Model

SD5 "Standard"

This solar collector was tested by the Florida Solar Energy Center (FSEC) in accordance with prescribed methods and was found to meet the minimum standards established by FSEC. The purpose of the tests is to verify initial performance conditions and quality of construction only. The resulting certification is not a guarantee of long term performance or durability.

DESCRIPTION

Gross Length	3.062 meters	10.05 feet
Gross Width	1.235 meters	4.05 feet
Gross Depth	0.093 meters	0.31 feet
Gross Area	3.782 square meters	40.70 square feet
Transparent Frontal Area	3.545 square meters	38.16 square feet
Volumetric Capacity	5.1 liters	1.35 gallons
Weight (empty)	44.4 kilograms	97.9 pounds
Number of Cover Plates	One	
Flow Pattern	Serpentine	

Efficiency Equations First Order $\eta = 64.1 - 632.6 (T_i - T_a)/I$

Second Order $\eta = 61.9 - 427.2 (T_i - T_a)/I - 2699.1 (T_i - T_a)/I^2$

Tested per ASHRAE 93-77 Units of $T_i - T_a/I$ are $^{\circ}\text{C}/\text{Watt}/\text{m}^2$

MATERIALS

Enclosure	Aluminum frame
Glazing	Kalwall Sun-Lite Premium II (fiberglass reinforced plastic)
Absorber	Formed copper fin bonded to copper tube, black paint
Insulation	Celotex Thermax (polyisocyanurate 2.54 cm)

RATING

The collector has been rated for energy output on measured performance and an assumed standard day. Total solar energy available for the standard day is $5045 \text{ watt-hour}/\text{m}^2$ ($1600 \text{ BTU}/\text{ft}^2$) distributed over a 10 hour period.

Output energy ratings for this collector based on the second-order efficiency curve are:

Collector Temperature	Energy Output	
Low Temperature, 35°C (95°F)	38,600 Kilojoules/day	36,600 BTU/day
Intermediate Temperature, 50°C (122°F)	28,600 Kilojoules/day	27,100 BTU/day
High Temperature, 100°C (212°F)	3,200 Kilojoules/day	3,100 BTU/day

1. COLLECTOR DESCRIPTION

1.1 Collector Identification

Manufacturer and Address:

Solar Development, Inc.
4180 Westroads Drive
West Palm Beach, FL 33407

Collector Model Number:

SD5 "Standard"

1.2 Collector Construction

Overall Dimensions:

Length: 3.062 m

Width: 1.235 m

Depth: 0.093 m

Overall Front Area: (length x width) - 3.782 m^2

Height of outlet above inlet when collector tilt is 90° : 1.045 m

Glazing:

Material: Kalwall

Thickness: 0.064 cm (0.025 inch)

Transmittance*: 88%

No. of Cover Plates: One

Transparent Frontal Dimensions:

Length: 3.007 m

Width: 1.179 m

Area: 3.545 m^2

Absorber:

Material: Copper alloy 110

Length: 2.997 m

Width: 1.194 m

Area: 3.578 m^2

Absorber Coating: Black paint by Cypress Coatings

Absorptivity*: Unknown

Emissivity*: Unknown

Air Spacing Glazing to Absorber: Approx. 4.5 cm

Insulation:

Type: Cellotex Thermex

Dimensions: 2.54 cm

K-Factor*: 0.02 Watts/m °C (0.13 Btu/hr-ft²-°F/in)

Heat Transfer Fluid:

Material: Water

Density: 977.81 kg/m³ at 70°C

Specific Heat: 4189.6 J/kg °C at 70°C

Collector Weight: 44.4 kg

Collector Weight/Area: 11.7 kg/m²

Collector Fluid Capacity: 5.1 liters

Collector Fluid Capacity/Area: 1.35 liters/m²

Normal Operating Temperature Range: 24°C to 93°C

Manufacturers Recommended Fluid Flow Rate: 2.8 liters/min (0.75 GPM)

Manufacturers Recommended Maximum Operating Pressure: 276 kilopascals (40 psig)
tested to 1103 (160 psig)

Cover Plate Wind Load Maximum*: 1436 Pascals (30 psf)

*Information provided by manufacturer; not verified by FSEC.

2. RESULTS

2.1 Introduction

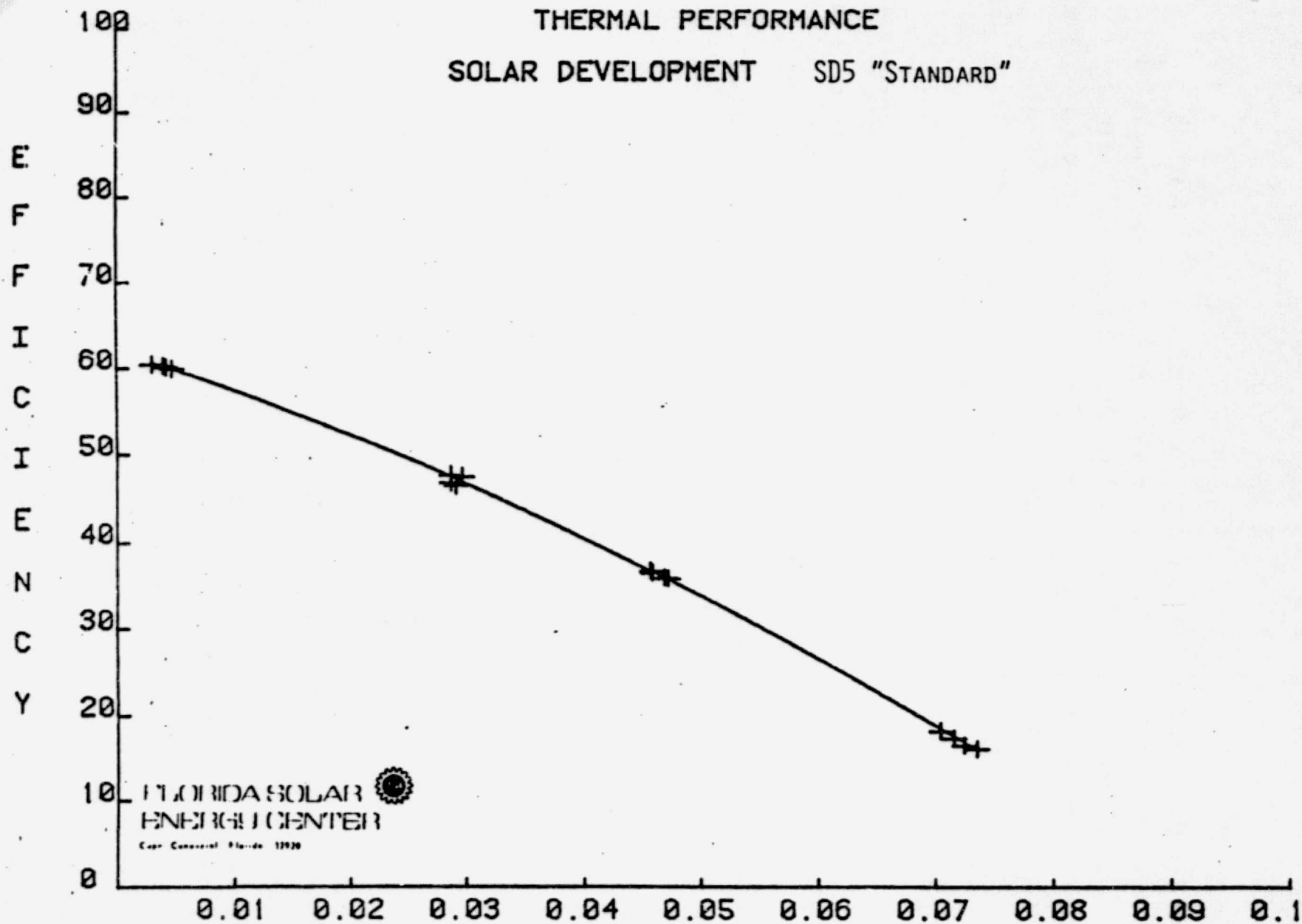
Results of the thermal performance tests are presented in graphical and tabular form. The first graph shows the efficiency plot in the International System of Units (Metric units). Following this is a comparison of the collector efficiency before and after exposure testing. Finally, the tabulated data is presented. The performance graphs and the tabulated data are also presented in Section 2.6 in English units of measure.

2.2 Explanation of Results

The Solar Development, Inc. model SD5 "Standard" solar collector was tested for time constant and thermal performance. The time constant was found to be 1.3 minutes. A thermal performance test was conducted during the period from 12 February to 14 February 1978. An incident angle modifier test will be conducted. After these tests were completed the collector was filled with water, capped with a pressure relief valve set at 414 kPa and placed on an exposure rack for a period of 40 days. During this period there were at least thirty days on with the total daily insolation was greater than 4730 watt-hours per square meter (1500 Btu/ft^2) and at least one day on which there was a four-hour period with a minimum insolation level of 1013 watts per square meter (321 Btu/hr-ft^2). During the exposure test the collector rack was adjusted to keep the angle between the incoming solar radiation and a normal to the collector surface less than five degrees at solar noon. On three of the last ten days of exposure, the collector was sprayed with water to simulate rain. A second thermal performance test was conducted during the period 21 April to 25 April 1978.

The second performance test revealed a slight decrease in performance, but within the required limits. After all the tests had been completed, the collector was disassembled and inspected. The inspection revealed minor outgassing deposits around the perimeter of the inside surface of the cover plate. No other evidence of deterioration was found.

THERMAL PERFORMANCE SOLAR DEVELOPMENT SD5 "STANDARD"



$$(T_I - T_A)/I \quad (C - S Q M)/W$$

$$EFFICIENCY = 61.9 - 427.2 DT/I - 2699.1 DT/I^2$$

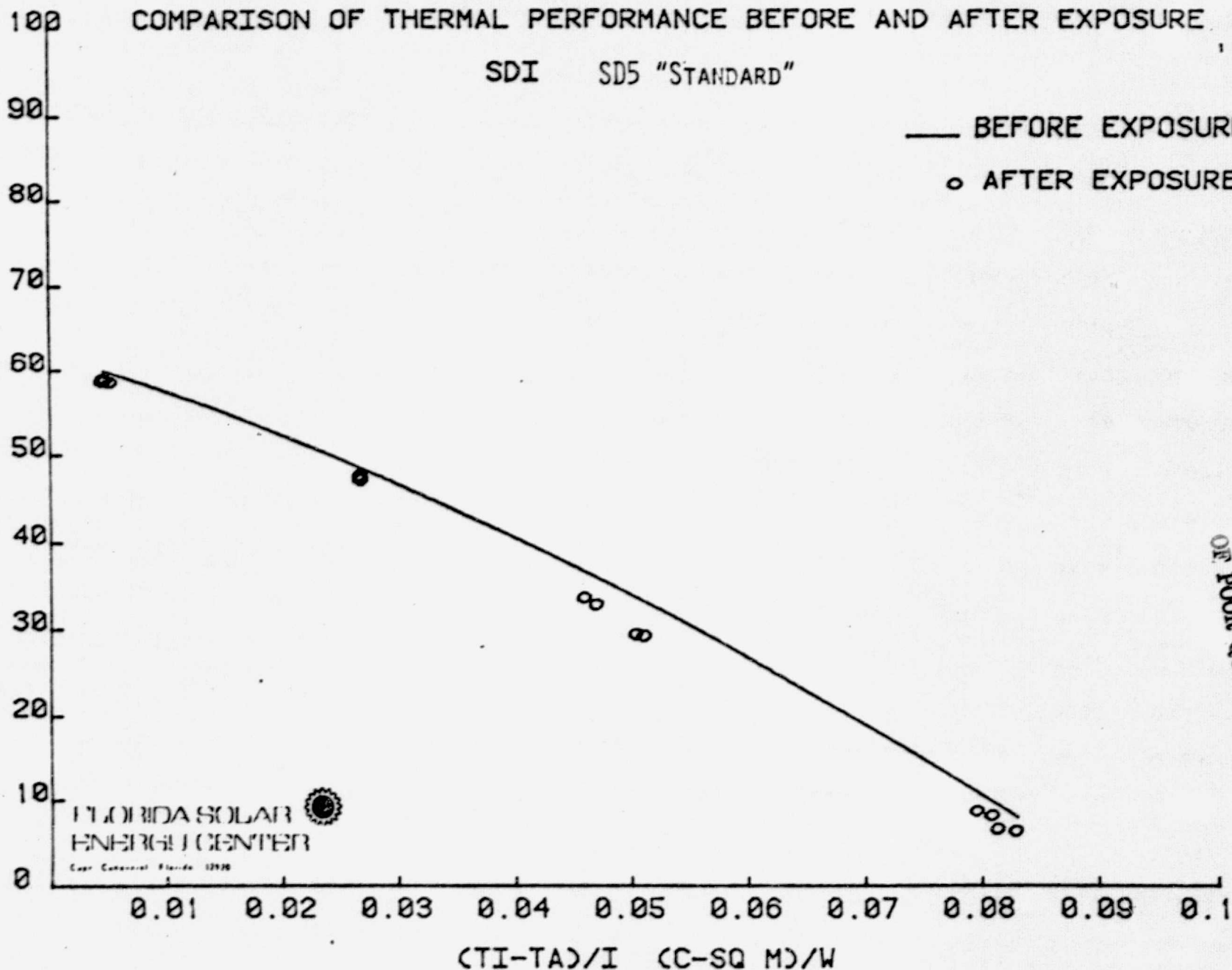
COMPARISON OF THERMAL PERFORMANCE BEFORE AND AFTER EXPOSURE

SDI SD5 "STANDARD"

— BEFORE EXPOSURE

○ AFTER EXPOSURE

E
F
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C
I
E
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C
Y



FLORIDA SOLAR
ENERGY CENTER

Clear Channel Florida 12920

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FLORIDA SOLAR ENERGY CENTER, CAPE CANAVERAL, FLORIDA

20 FEB 79

MANUFACTURER: SOLAR DEVELOPMENT

MODEL: SD5 "Standard"

AREA = 0.1100 m²

TEST:	DATE:	SOLAR TIME:	TA :	TE :	FLOW :	AVE IN :	TOTAL IN :	DEL :	EFFIC :	TA/TA :	
:	:	START: END :	(C) :	(C) :	(C) :	L/MIN: W/50 W :	W/50 W :	10-MIN :	% :	(C-50 W)/W :	
4	2/12/78	10:23 10:29	16.9	68.3	73.4	4.20	1089.3	325853.	25.7	35.7	0.0472
5	2/12/78	10:28 10:33	17.3	68.5	73.6	4.22	1092.1	327622.	25.8	36.0	0.0467
6	2/12/78	10:41 10:46	17.4	68.2	73.5	4.17	1104.3	331344.	26.3	36.6	0.0461
12	2/12/78	11:18 11:23	17.6	68.4	73.8	4.16	1111.2	333333.	27.2	36.8	0.0451
13	2/12/78	12:13 12:18	18.0	50.3	57.2	4.18	1124.7	337407.	35.3	47.7	0.0287
20	2/12/78	12:53 12:58	18.4	50.6	57.5	4.14	1122.0	336587.	35.0	46.8	0.0287
23	2/12/78	13:22 13:28	18.2	50.7	57.6	4.18	1111.3	333388.	34.7	47.5	0.0282
25	2/12/78	13:33 13:38	18.2	50.2	56.9	4.17	1101.4	330420.	33.8	46.5	0.0291
27	2/12/78	14:48 14:53	17.9	90.7	93.2	4.16	1035.4	310609.	12.7	18.3	0.0704
28	2/12/78	14:53 14:58	17.8	91.3	93.6	4.16	1027.2	308172.	12.0	17.4	0.0716
29	2/12/78	14:58 15: 3	18.1	91.8	94.0	4.17	1017.3	305176.	11.3	16.6	0.0724
30	2/12/78	15: 3 15: 9	18.1	92.2	94.3	4.17	1009.0	302715.	10.9	16.2	0.0731
39	2/14/78	10:27 10:30	19.5	23.2	31.9	4.13	1108.7	332624.	43.9	60.1	0.0002
40	2/14/78	10:30 10:35	18.2	23.5	32.2	4.13	1111.8	333535.	43.9	59.9	0.0047
45	2/14/78	14:47 14:52	21.6	24.8	33.2	4.17	1075.4	322605.	42.4	60.4	0.0030
47	2/14/78	14:57 15: 2	21.0	25.2	33.3	4.17	1045.7	313783.	41.1	60.2	0.0041

THE FIRST ORDER EFFICIENCY CURVE IS: EFFICIENCY = 0.11 - 0.002.8 (T - 15.71)
THE UNITS ON (T-15.71) ARE (C-50 W)/W.

THE SECOND ORDER EFFICIENCY CURVE IS: EFFICIENCY = 0.11 - 0.002.8 (T - 15.71) + 0.00001 (T - 15.71)²
THE UNITS ON (T-15.71) ARE (C-50 W)/W. 0.00001 IS

FLORIDA SOLAR ENERGY CENTER, CAPE CANAVERAL, FLORIDA

20-FEB-70

MANUFACTURER: SOLAR DEVELOPMENT

MODEL: SD5 "Standard"

AREA = 3.702 CM²

TEST	TILT	HAZIN	INCL	MASS	SPEC HEAT	IN P	WIND	WIND	DIF IN	Z	DATE	11-1A
	DEG	DEG	DEG	KG/SEC	J/(KG C)	KN/CM ²	M/S	DIR	W/CM ²	H	INSOL.	(C)
4	XXXX	XXXXXX	0.	0.0685	4190.1	354.5	1.2	326.	155.3	14.3		31.4
5	XXXX	XXXXXX	0.	0.0688	4190.2	353.1	1.0	326.	154.0	14.1		31.2
6	XXXX	XXXXXX	0.	0.0680	4190.1	364.4	1.4	376.	154.0	14.0		30.8
12	XXXX	XXXXXX	0.	0.0678	4190.2	374.2	1.4	108.	159.1	14.3		30.3
14	XXXX	XXXXXX	0.	0.0687	4181.8	330.8	1.3	103.	158.5	14.1		32.3
20	XXXX	XXXXXX	0.	0.0679	4181.9	320.1	1.3	110.	152.3	14.3		32.2
23	XXXX	XXXXXX	0.	0.0687	4181.9	331.4	1.2	99.	153.3	14.7		32.5
25	XXXX	XXXXXX	0.	0.0686	4181.7	350.4	1.7	81.	158.0	15.1		32.1
27	XXXX	XXXXXX	0.	0.0668	4207.3	362.8	1.4	82.	157.8	16.2		72.9
30	XXXX	XXXXXX	0.	0.0669	4207.8	363.0	1.0	82.	159.1	16.1		73.3
29	XXXX	XXXXXX	0.	0.0669	4208.2	363.3	1.0	82.	162.8	16.0		73.7
30	XXXX	XXXXXX	0.	0.0670	4208.6	363.4	1.6	86.	161.0	16.0		74.2
32	XXXX	XXXXXX	0.	0.0686	4178.8	350.7	4.0	267.	156.9	14.3		31.7
40	XXXX	XXXXXX	0.	0.0686	4178.7	351.0	3.5	294.	159.7	14.4		31.3
45	XXXX	XXXXXX	0.	0.0693	4178.4	390.2	4.4	272.	167.6	15.8		31.2
47	XXXX	XXXXXX	0.	0.0693	4178.4	389.9	3.2	299.	165.0	15.8		4.2

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WIND	Wind speed (meters/second or miles/hour)
WIND DIR	Wind direction (degrees east from north)
DIF IN	Diffuse instantaneous insolation (watts/square meter or BTU/hour-square foot)
% DIFF INSOL	Percent of the incoming radiation that was diffuse
TI-TA	Temperature difference between the inlet fluid temperature and ambient air ($^{\circ}\text{C}$ or $^{\circ}\text{F}$)

Notes:

1. The test number is simply a number assigned for use by FSEC
2. Stars indicate that no data was taken on the indicated parameter during that test.
3. The data presented in the test report best represent the performance of the collector during testing. The actual data points were chosen to be at the temperatures recommended by ASHRAE.

2.4 Results of Static Tests

2.4.1 Pressure Test

Date of Test: 10 December 1977

Static Test Pressure: 1103 kilopascals (160 psig)

Duration of Test: 15 minutes

2.4.2 Pressure Drop Test

Date of Test: 23 April 1978

Air Temperature: 25.6°C (78.1°F)

Inlet Temperature: 27.1°C (80.7°F)

Flow Rate: 4.24 L/min (1.12 GPM)

Inlet Pressure: 142.6 kPa (20.7 psig)

Pressure Drop: 8.00 kPa (1.16 psi)

2.4.3 Exposure Test

Start Date: 25 February 1978

Completion Date: 6 April 1978

No. of Days of Exposure: 40

No. of Days of Exposure when insolation exceeded
4730 watts/m² (1500 BTU/ft²): 30

Pressure Relief Setting: 414 kPa (60 psig)

Spray Tests:

Dates:	30 March	02 April	03 April 1978
Insolation:	946 Watts/m ² (300 Btu/hr-ft ²)	1060 Watts/m ² (336 Btu/hr-ft ²)	996 Watts/m ² (316 Btu/hr-ft ²)

2.4.4 Inspection Results:

Cover Plate: a minor amount of outgassing deposit was detected
around the perimeter of the inside surface of the cover plate.

Absorber Plate: No evidence of deterioration

Absorptive Coating: No evidence of deterioration

Collector Enclosure: No evidence of deterioration

Insulation: No evidence of deterioration

Gaskets, Caulking &
Sealants: No evidence of deterioration

2.3 Computer Printout Key

TEST	Number assigned to the data for a particular test
DATE	Date on which the test was performed
SOLAR TIME	Solar time at the start and finish of the test
TA	Ambient air temperature ($^{\circ}\text{C}$ or $^{\circ}\text{F}$)
TI	Temperature of the transfer fluid at the collector inlet ($^{\circ}\text{C}$ or $^{\circ}\text{F}$)
TE	Temperature of the transfer fluid at the collector exit ($^{\circ}\text{C}$ or $^{\circ}\text{F}$)
FLOW	Volumetric flow rate of the transfer fluid (liters/minute or gallons/minute)
AVE IN	Average instantaneous insolation (watts/square meter or BTU/hour-square foot)
TOTAL IN	Total (integrated) insolation in the plane of the collector during the test period (joules/square meter or BTU/square foot)
DEL T	Total (integrated) temperature rise across the collector during the test period (degree centigrade minutes or degree fahrenheit minutes)
EFFIC	Calculated collector efficiency for the test period (percent)
(TI-TA)/I	Value calculated for the abscissa of the efficiency graph I = average instantaneous insolation. ($^{\circ}\text{C}$ - square meter/watt or $^{\circ}\text{F}$ - hour - square foot/BTU)
TILT	Angle which the collector was tilted from the horizontal (degrees)
AZIM	Collector azimuth angle (degrees from due south; east positive)
INCI	Angle between the incoming radiation and a normal to the collector surface (degrees)
MASS	Mass flow rate of the transfer fluid (kilograms/second or pounds mass/minute)
SPEC HEAT	Specific heat of the transfer fluid (joules/kilogram - $^{\circ}\text{C}$ or BTU/pound mass - $^{\circ}\text{F}$)
IN P	Gage pressure at the collector inlet (kilonewtons/square meter or pounds/square inch)

2.5 Explanation of Efficiency Curve

The test data is presented in tabular form and as an efficiency curve. The efficiency curve is based on the following equation:

$$\eta = F_R(\tau\alpha)_e - F_R U_L \frac{(T_i - T_a)}{I}$$

where:

- η = collector efficiency
- F_R = heat removal factor
- $(\tau\alpha)_e$ = effective transmissivity-absorptivity product
- U_L = over-all heat loss coefficient
- T_i = transfer fluid temperature at the collector inlet
- T_a = ambient air temperature
- I = instantaneous level of solar radiation

The standard form of the equation of a straight line is:

$$Y = b + mX$$

where:

- b = Y axis intercept
- m = slope

From these two equations it can be seen that a straight line should result if a plot of efficiency versus the quantity $\frac{T_i - T_a}{I}$ is made and if the slope and intercept functions can be assumed constant. It then becomes apparent that the slope of the line is a function of the over-all heat loss coefficient and the Y axis intercept is a function of the transmissivity of the cover plate(s) and the absorptivity of the absorber plate(s). In reality, however, U_L is not constant under the test conditions since it varies with the temperature of the collector and ambient weather conditions. Therefore a second order curve is used to describe the thermal performance of the collector. That is:

$$Y = c + bX + aX^2$$

The intercept is still related to $(\tau\alpha)_e$ and the slope at any point on the curve is proportional to the heat loss rate for that value of $\frac{T_i - T_a}{I}$.

2.6 Performance Test Results, English Units

Following is a repetition of the thermal performance curve. Although identical to the previous graph (see Sec. 2.1) in content, this graph and computer printout is presented in English units.

The efficiency curve does not give absolute values for the overall heat loss coefficient and $(\tau\alpha)_e$ since both are multiplied by the factor F_R . However, the plot does indicate relative values for these two quantities that can be used for comparing collectors. Determination of the absolute values of $(\tau\alpha)_e$ and U_L would require additional measurements beyond the tests performed.

The X quantity, $\frac{\dot{T}_i - \dot{T}_a}{I}$, can be determined from measurements made during testing. The collector efficiency can be calculated from the following equation:

$$\eta = \frac{\dot{m} C_p \int \Delta T dt}{A \int I dt}$$

where:

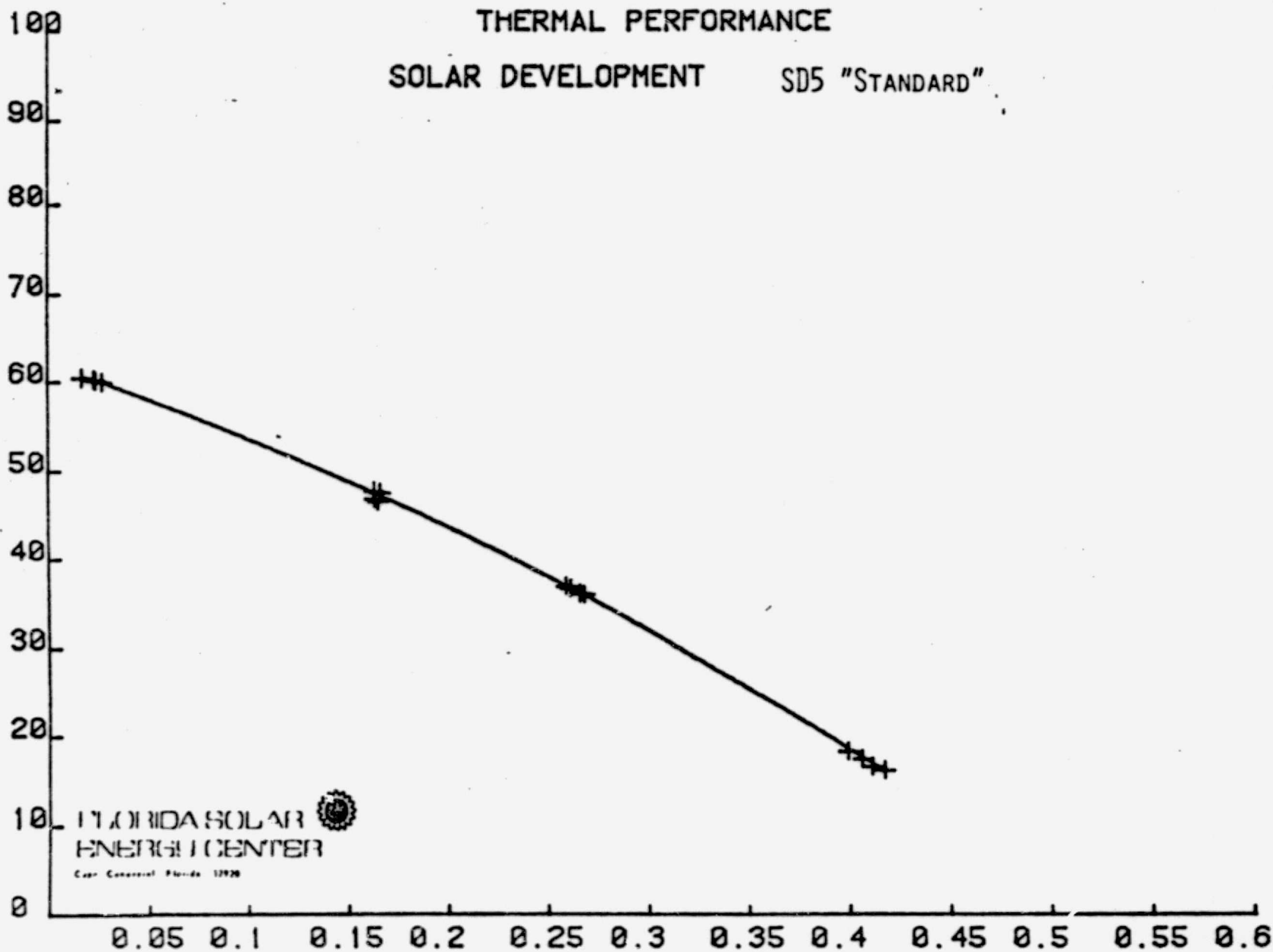
- \dot{m} = mass flow rate of the transfer fluid
- C_p = specific heat of the transfer fluid
- $\int \Delta T dt$ = integrated (total) temperature rise across the collector
- A = gross frontal area
- $\int I dt$ = integrated (total) solar radiation received by the collector during the test.

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The data is collected during a series of test runs. Each data point, represented as a plus sign on the efficiency plot, is the result of a test run, the exact length of the run being determined by the collector time constant. The line drawn on the plot is a second order least squares curve fit of the data points.

THERMAL PERFORMANCE SOLAR DEVELOPMENT SD5 "STANDARD"

84
E
F
F
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C
I
E
N
C
Y



FLORIDA SOLAR ENERGY CENTER
Cape Canaveral Florida 32926

$$\text{EFFICIENCY} = 61.9 - 75.3 \text{ DT}/I - 83.8 \text{ DT}/I^2$$

COMPARISON OF THERMAL PERFORMANCE BEFORE AND AFTER EXPOSURE

SDI

SD5 "STANDARD"

— BEFORE EXPOSURE

○ AFTER EXPOSURE

E
F
F
I
C
I
E
N
C
Y

100
90
80
70
60
50
40
30
20
10
0

FLORIDA SOLAR
ENERGY CENTER

Cape Canaveral, Florida 32916

0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6

$(T_i - T_a)/I$ (F-HR-SQ FT)/BTU

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MANUFACTURER: SOLAR DEVELOPMENT

MODEL: SD5 "Standard"

AREA = 40.71 sq ft

TEST: DATE: SOLAR TIME: TA : TI : TE : FLUX: AVE IN : TOTAL IN : DEL T : EFFICI: (11-18771
 : : START: END : (F) : (F) : (F) : (BTU/HR-FT2) (BTU/HR-FT2) (MIN) : % : (BTU/HR-FT2)/B

4	2/13/78	10:23	10:23	82.4	154.9	164.1	1.111	343.8	28.8	48.3	33.9	0.288
5	2/13/78	10:23	10:33	83.1	155.3	164.4	1.116	346.4	28.7	48.3	38.0	0.286
6	2/13/78	10:41	10:41	83.4	154.8	164.2	1.103	339.4	27.2	48.3	38.2	0.281
11	2/13/78	11:18	11:23	83.7	155.1	164.8	1.099	352.8	29.4	49.0	33.8	0.257
12	2/13/78	12:13	12:13	84.3	121.5	135.0	1.105	356.8	27.7	83.8	47.7	0.183
13	2/13/78	12:57	12:57	85.1	123.8	135.5	1.092	355.7	27.7	82.9	48.8	0.188
14	2/13/78	13:23	13:23	84.8	123.2	135.6	1.105	352.5	29.4	82.5	47.8	0.185
15	2/13/78	13:31	13:31	84.7	122.4	134.4	1.103	349.4	29.1	83.8	48.8	0.185
98	2/13/78	14:48	14:53	84.2	195.3	199.8	1.099	323.4	27.4	22.7	18.8	0.339
16	2/13/78	14:57	14:57	81.1	196.4	200.6	1.079	323.7	27.2	21.8	17.4	0.408
17	2/13/78	15:13	15:13	84.6	197.2	201.2	1.101	322.7	28.7	20.4	18.8	0.411
18	2/13/78	15:13	15:13	84.5	198.0	201.8	1.102	330.1	28.7	19.7	18.2	0.417
19	2/13/78	16:25	16:30	85.4	73.8	87.4	1.072	311.7	27.3	79.1	60.1	0.024
20	2/13/78	16:30	16:35	84.8	74.3	87.9	1.091	352.7	28.4	79.1	59.7	0.027
21	2/13/78	14:11	14:52	76.7	76.7	91.8	1.102	311.1	28.4	78.4	60.4	0.017
22	2/13/78	14:57	15:12	87.7	77.3	91.9	1.102	331.3	27.6	74.1	60.2	0.023

THE FIRST ORDER EFFICIENCY CURVE IS: EFFICIENCY = 34.1 -111.5 (11-18771
 THE UNITS ON (11-18771 ARE (BTU/HR-FT2)/BTU.

THE SECOND ORDER EFFICIENCY CURVE IS: EFFICIENCY = 34.7 -75.3 (11-18771 -83.8 (11-18771
 THE UNITS ON (11-18771 ARE (BTU/HR-FT2)/BTU. (11-18771

FLORIDA SOLAR ENERGY CENTER, CAPE CANAVERAL, FLORIDA

20 FEB 70

MANUFACTURER: SOLAR DEVELOPMENT

MODEL: SD5 "Standard"

AREA: 1.00

TEST : TILT : AZIM : LOST : MASS : SPEC HEAT : IN P : WIND : WIND : DIR IN : 2 DIFF : 11 : 12
: DEG : DEG : DEG : LBS/MIN : BTU/(LBS-F) : PSI : MPH : DIR : R/H-FT2 : 1000 : 1.07

4	****	****	0.0	9.06	1.001	51.4	2.7	326.	47.0	14.3	72.0
5	****	****	0.0	9.10	1.001	51.7	2.3	326.	48.0	14.1	72.1
6	****	****	0.0	8.99	1.001	52.9	3.2	350.	47.1	14.0	71.4
12	****	****	0.0	8.97	1.001	54.3	3.1	108.	50.0	14.0	71.4
14	****	****	0.0	9.09	0.999	48.0	2.0	103.	50.3	14.1	70.1
20	****	****	0.0	8.99	0.999	47.0	2.7	110.	51.5	14.0	70.1
23	****	****	0.0	9.09	0.999	40.1	2.0	77.	51.7	14.7	67.2
25	****	****	0.0	9.07	0.999	47.9	3.6	51.	52.7	13.1	71.7
27	****	****	0.0	8.84	1.005	52.3	3.2	92.	50.2	13.2	71.1
28	****	****	0.0	8.84	1.005	52.0	3.6	62.	50.4	13.1	71.1
29	****	****	0.0	8.85	1.005	53.0	3.4	62.	51.0	13.0	72.0
30	****	****	0.0	8.86	1.005	53.1	3.7	63.	51.2	13.0	73.0
39	****	****	0.0	9.08	0.998	50.9	7.0	257.	50.1	14.0	67.4
40	****	****	0.0	9.08	0.998	50.7	7.8	294.	50.7	14.4	69.3
45	****	****	0.0	9.16	0.998	50.0	9.8	272.	53.2	15.0	67.7
47	****	****	0.0	9.16	0.990	50.0	7.2	277.	52.3	15.8	71.0

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TACO

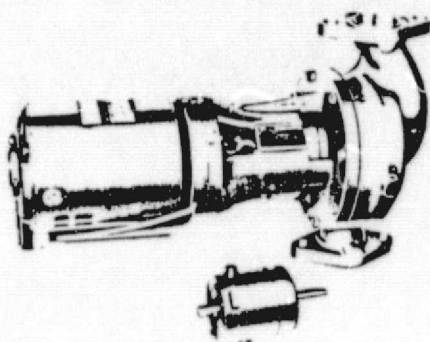
NUMBER

SD 300-1-12

CARTRIDGE TYPE IN-LINE PUMPS

EFFECTIVE: APRIL 1, 1974
SUPERSEDES: NEW

NOTE: TACO Submittal Data Sheet
SD 300-1-5 SD 300-1-8
SD 300-1-9 SD 300-1-10
are OBSOLETE and are
NO LONGER VALID.



JOB: **RADEMAKER CORPORATION**
LOUISVILLE, KENTUCKY

Date Submitted:

By:

LOCATION	PUMP SIZE	GPM	HEAD	PHASE
P1	MODEL # 1600			
P2	MODEL # 1610			

SPECIFICATIONS:

MOTORS

1750 RPM, Three Phase 200V or 230/460V 60C
Sleeve Bearing Motors. Also available in Single
Phase with overload protection except 3 HP.

BODY

Cast Iron with flanged in-line connections.
Companion flanges are included

IMPELLER

Cast Bronze, Closed, Dynamically Balanced.

DRIVE COUPLING

Non-Metallic / Vibration Dampening

SHAFT

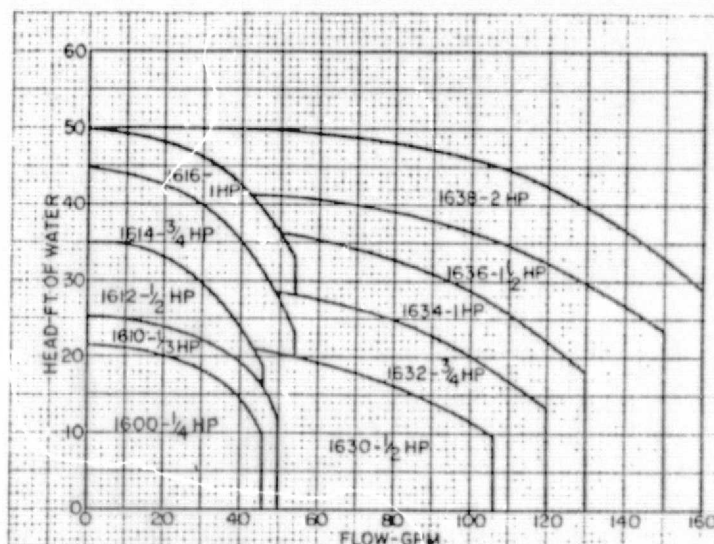
Stainless Steel with Cupro-Nickel Sleeve.

FRAME

Sleeve Bearing, Disc Type, Oil lubricated. RE-
MOVABLE BEARING CARTRIDGE FITS ALL
MODELS. Dip Stick to measure oil level.

MECHANICAL SEAL

Standard-250°F Operating Temp.

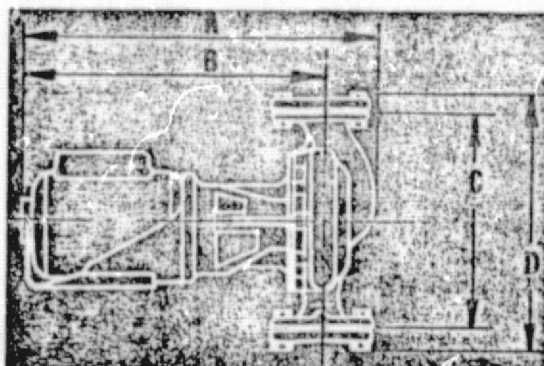


WORKING PRESSURE

175 PSI... in accordance with ASA B16.1

NOTE: Flanges are tapped for gauges

SIZES & DIMENSIONS:



MODEL NO.	Fig. Size	MOTOR DATA			DIMENSIONS			
		HP	60 Hz 1 Ph.	60 Hz 3 Ph.	A	B	C	D
1600	1 1/2	1/4	115V	NOT AVAILABLE	19	16 1/2	10 1/4	12 7/8
1610		1/2	115V		19	16 1/2	10 1/4	12 7/8
1612	2	1/2	115/230	200 or 230/460	21	18 1/2	13 1/2	16 1/2
1614		3/4			21 1/2	19	13 1/2	16 1/2
1616		1			22	19	14 1/2	17 3/8
1630		1/2			21 1/2	18	13 1/2	16 1/2
1632		3/4			22	18 1/2	13 1/2	16 1/2
1634		1			22 1/2	19	13 1/2	16 1/2
1636		1 1/2			24 1/2	21	16 1/2	19 1/2
1638		2			26 1/2	23	16 1/2	19 1/2

Taco Heaters of Canada, Ltd.
3090 Lenworth Drive
Mississauga, Ontario

Taco, Inc. 1160 Cranston Street, Cranston, Rhode Island 02920 U.S.A.
printed in U.S.A.

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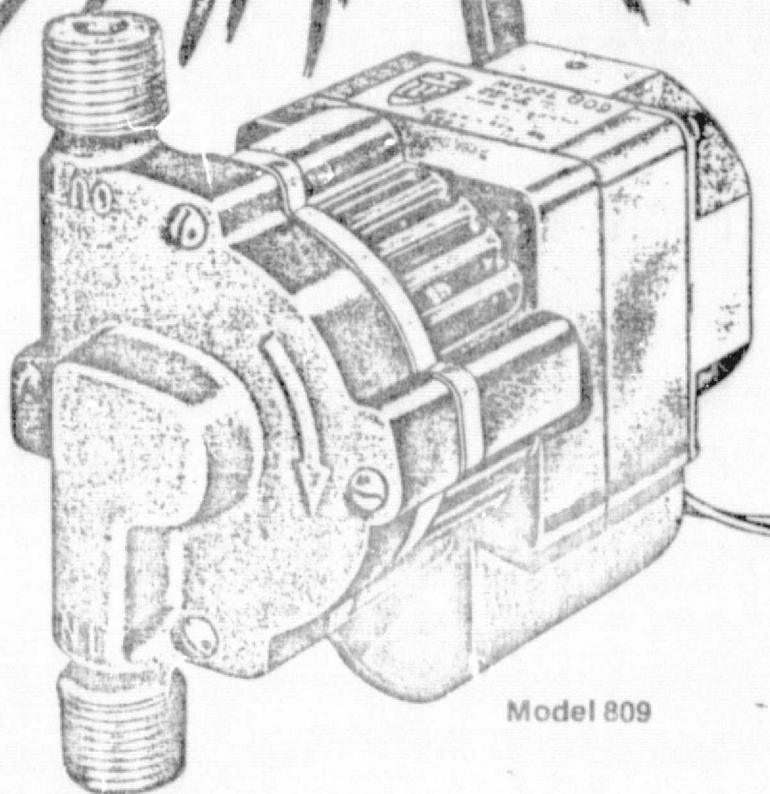
MARCH CIRCULATING PUMPS FOR SOLAR ENERGY SYSTEMS

March circulators are proven for solar energy applications — have been first choice since 1967. From the 3 gpm Model 809 to the large 22 gpm models, all are powered by energy saving magnetic drive, the most efficient drive possible.

Magnetic drive, with no troublesome shaft seals is uniquely energy conscious, converting full motor horsepower into pumping power. The 809's 1/200 hp motor draws only 0.36 amp — costs less to operate than a 40-watt light bulb. And since there's no shaft seal, there's no seal wear, no seal leakage... ever!

Dynamically balanced magnets combined with micro-balanced motor fan assures extremely quiet operation. Bronze head resists rust and foreign deposit build-up. The compact 809 weighs just over four pounds and is easily installed either vertically or horizontally.

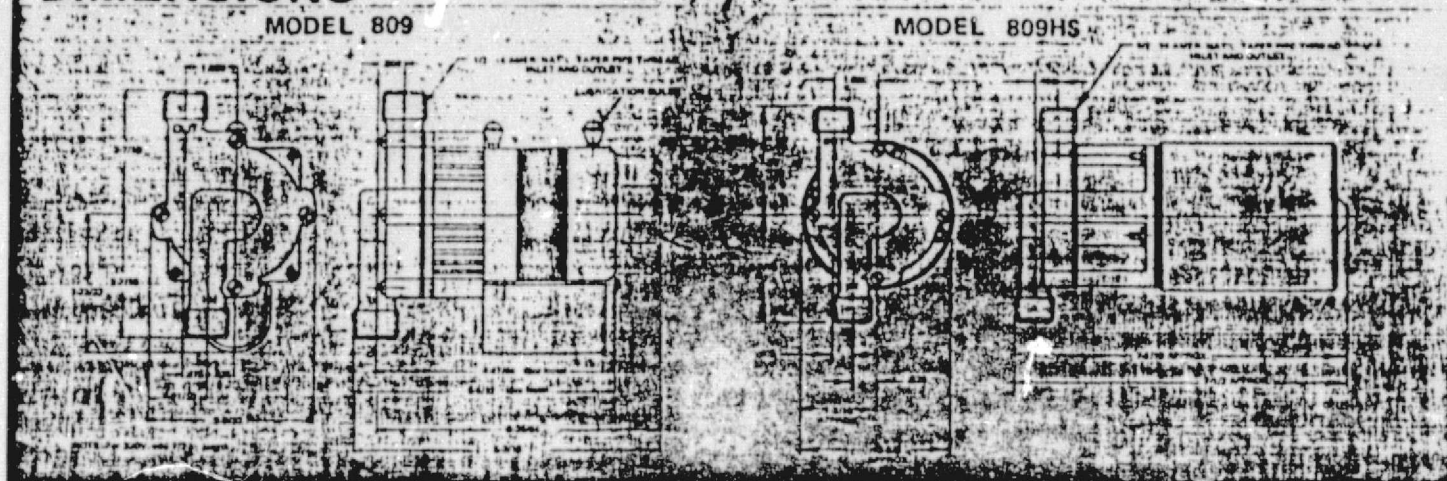
March solar energy pumps are designed for commercial service as well as residential applications. In addition to the 3 gpm model shown, others are available with capacities to 22 gpm and heads to 45 feet. For special applications requiring design assistance, contact the March corporate office.



Model 809

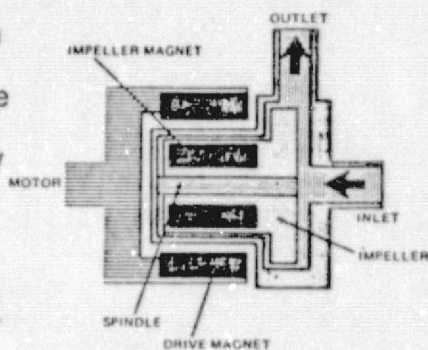
Pump P-3

DIMENSIONS

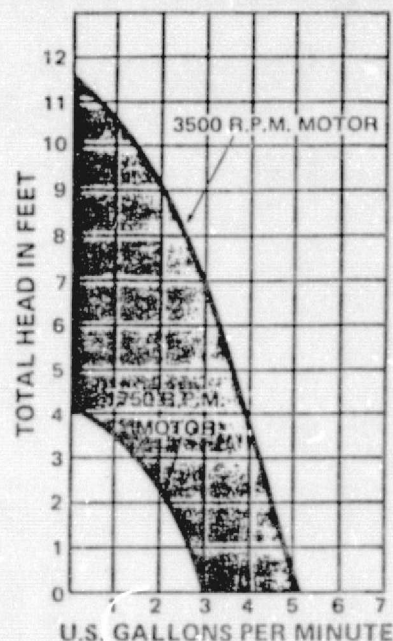


MAGNETIC DRIVE

March's proven magnetic drive eliminates the troublesome, old-fashioned shaft seal. There can be no seal wear, power-robbing friction or leakage thru the seal. Impeller and drive magnets are permanent ceramic type. They prevent slippage and insure that full motor horsepower is converted into pumping power. Energy requirements are lowered as all the energy produced by the motor is utilized, especially important in solar systems. March seal-less drive also provides for faster, easier motor service, as the motor can be removed without draining, refilling and reheating the system.



PERFORMANCE



SPECIFICATIONS

Model	Max. Flow	Max. Head	Max. PSI	Inlet & Outlet	Motor							Pack Wt.
					HP	RPM	Volts	Cycles	Phase	Watts	Amps.	
809 809DF 809DF-24	3 gpm	4.1	1.8	1/2" MPT	1/200	1750	115 or 230 24	60	Single	24	.36 or .26	4.5 lbs.
809HS	53 gpm	11.6	5.0	1/2" MPT	1/25	3500	115 or 230	60	Single	80	1.2 or .6	8.0 lbs.

Model 809

The original solar energy circulating pump.

Model 809 HS

3500 RPM model for almost twice the capacity and nearly three times the head.

Model 809 DF

Dual fans for quiet, cool operation in closed-in or hot environments.

Model 809 DF-24

As above except 24 volt version.

Higher capacity models are also available. Contact March or nearest March distributor for details.



MARCH
MANUFACTURING CO., INC.

1819 PICKWICK AVENUE
GLENVIEW, ILLINOIS 60025
(312) 729-5300 TELEX 72-4378

1" 552 SERIES HIGH CAPACITY REVERSIBLE MOTOR OPERATED VALVES

Valve Series	Pipe Connections and Diameters (Threaded Valve Connections are NPT Conduit Connector is 1/2" STD)	Model	Valve Ports - Size		Service Port Cv Factor	Optional Equipment
			Service End B	By-Pass End A	(Based on U.S. gal.)	(See Below)
Fan coil valves for chilled water and not water applications						
552BR3302	1" Pipe Thread Female	2-way	.6"		9.2	2,3,6,8
552BR3303	1" Pipe Thread Female	3-way	.65"	.5"	9.	2,3,6,8

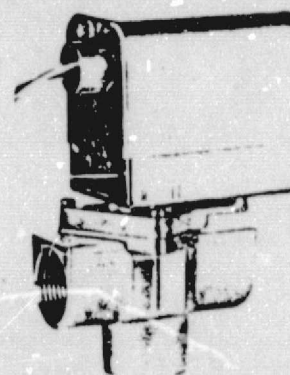
Steam and hot water valves

552BR3402	1" Pipe Thread Female	2-way	.6"		9.2	2,3,6,8
552BR3403	1" Pipe Thread Female	3-way	.65"	.5"	9.	2,3,6,8

CYCLE TIME

Full open to full close:

2 way — 18 seconds
3 way — 24 seconds



The new 552 Series, 1", high capacity valve is motor driven to both the open and the closed position. It is designed for both chilled water and hot water on larger fan coil applications.

The manual lever is self-unlocking upon energization of the opening coil.

"BR" SERIES REVERSIBLE MOTOR OPERATED VALVES FOR HEATING AND COOLING FAN COIL APPLICATION

DESIGNED TO OPERATE ON HIGH DIFFERENTIAL APPLICATIONS

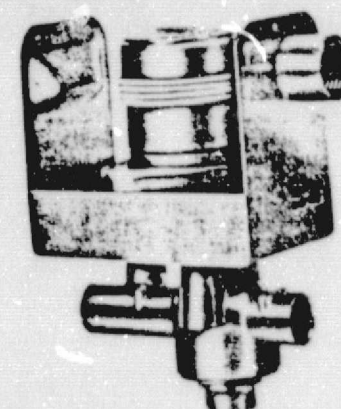
Valve Series	Pipe Connections and Diameters (Threaded Valve Connections are NPT Conduit Connector is 1/2" STD)	Model	Valve Ports - Size		Service Port Cv Factor (Based on U.S. gal.)	Optional Equipment (See Below)
			Service End B	By-Pass End A		
681-BR-307	1/2" Pipe Thread Female	2-way	5/16"		2.4	2,3,4,6,8,9
681-BR-309	1/2" Pipe Thread Female	3-way	7/16"	5/16"	5.5	2,3,4,6,8,9
687-BR-307	45° (SAE) Inverted Flare 1/2" Copper (5/8" O.D.)	2-way	5/16"		2.4	2,3,4,6,8,9
687-BR-309	45° (SAE) Inverted Flare 1/2" Copper (5/8" O.D.)	3-way	7/16"	5/16"	4.4	2,3,4,6,8,9
672-BR-307	3/4" Pipe Thread Female	2-way	5/16"		2.4	2,3,4,6,8,9
672-BR-309	3/4" Pipe Thread Female	3-way	7/16"	5/16"	5.5	2,3,4,6,8,9
654-BR-307	5/8" O.D. Sweat	2-way	5/16"		2.4	2,3,4,6,8,9
654-BR-309	5/8" O.D. Sweat	3-way	7/16"	5/16"	4.8	2,3,4,6,8,9
635-BR-307	7/8" O.D. Sweat	2-way	5/16"		2.4	2,3,6,8
635-BR-309	7/8" O.D. Sweat	3-way	7/16"	5/16"	5.4	2,3,6,8

STEAM AND HIGH TEMPERATURE WATER VALVES

Same as above except first number after "BR" changes to "H"

EXAMPLE: 681BR407

See page four for 400 type specifications.



The "BR" Series valve is motor driven to the open and the closed position. Its high differential capabilities make it a real "trouble job" problem solver.

ORDERING EXAMPLE

Valve Series	Lead Length	Power Requirements	Optional Equipment
654-BR-309	18	B	O
Obtain Valve Series No. from above table of standard Valve Models.	A standard 18" lead is supplied with all valves. Lead Lengths other than 18" can be supplied. Valves ordered with auxiliary sealed switches only available with 18" leads.	Select power requirement from table below enter suffix symbol when ordering. 24 Volt, 50/60 Cy., (5.5 Watts) Suffix - A 120 Volt, 50/60 Cy., (5.5 Watts) Suffix - B 240 Volt, 50/60 Cy., (5.5 Watts) Suffix - C (other motor energizations available at extra charge.) 208 Volt, 50/60 Cy. Suffix - D 208/230 Volt, 50/60 Cy. Suffix - S 277 Volt, 50/60 Cy. Suffix - T 24 Volt, 50 Cy. Suffix - J 125 Volt, 50 Cy. Suffix - K 240 Volt, 50 Cy. Suffix - L 208 Volt, 50 Cy. Suffix - M 100 Volt, 50/60 Cy. Suffix - N 200 Volt, 50/60 Cy. Suffix - P 220 Volt, 50 Cy. Suffix - R	Description No. Adjust-O-Flow 4 Sealed End Switch 8 Adjust-O-Flow and Sealed End Switch 9 Two Wire Control Package 2 Strap-on Change-over Switch With Two Wire Control Package 6 Two Wire Control Package And Encapsulated End Switch. 3

654-BR-309-18B0- DESCRIPTION: 5/8" O.D. SWEAT VALVE, THREE-WAY, 120 VOLT, 18" LEADS

Begin with complete Valve Series Number. Add letters and numbers denoting Lead Length.

Power requirements and Optional Equipment as shown above.

AUXILIARY SWITCH

For control panel monitoring or operating auxiliary equipment on standard models. It is actuated on the valve opening cycle and is reset as valve closes. For pilot duty only.

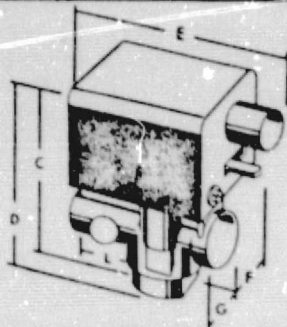
STRAP-ON SUMMER/WINTER CHANGE OVER SWITCH

Encapsulated switch completely sealed against moisture and factory wired to operate valve motor only. It will operate on thermostat heating contacts with water temperatures of 88° F. or higher. With water temperatures of 60° F. or lower the valve will operate on thermostat cooling contacts.

PREFIXES FOR CONDUIT TYPES

The prefixes "61", "62", "63", "64", and "65" before the valve part number designates the following:

Prefix	Countries	Conduit	Type of Valve Connection
"61"	Finland only	13/16 - 18	BSP-PL or 16MM (1/2" Nom.) Water Tube Sweat
"62"	Spain only	3/4 - 18	BSP-TR or 16MM (1/2" Nom.) Water Tube Sweat
"63"	E.E.C.	3/4 - 15	BSP-PL or 16MM (1/2" Nom.) Water Tube Sweat
"64"	U.S.A. (Str. Pipe)	1/2 - 14	NPT or 5/8" O.D. (1/2" Copper) Water Tube Sweat
"65"	United Kingdom	3/4 - 16	BSP-PL or .596" O.D. (1/2" Nom.) Water Tube Sweat



ERIE MOTORHOLS	MEASUREMENT	C	D	E	F	G	L
"BR" SERIES	CENTIMETERS	12.7	14.5	11.2	3.6	2.6	9.0
	INCHES	5.0	5.7	4.4	1.4	1.0	3.5
552 SERIES	CENTIMETERS	14.5	16.5	11.2	3.6	3.1	12.0
	INCHES	5.7	6.6	4.4	1.4	1.2	4.6

WIRING DIAGRAMS

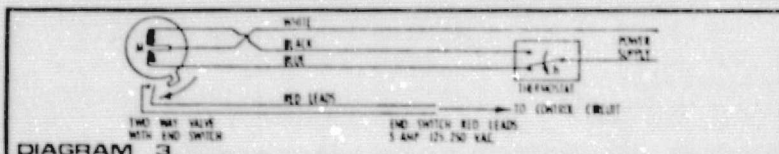
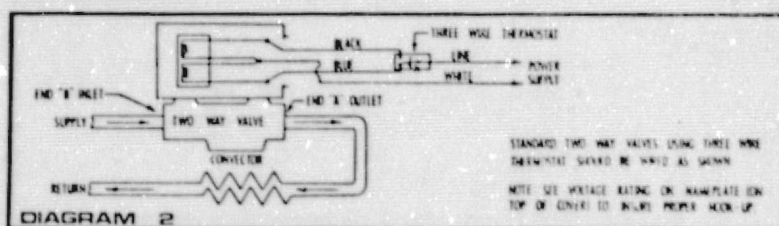
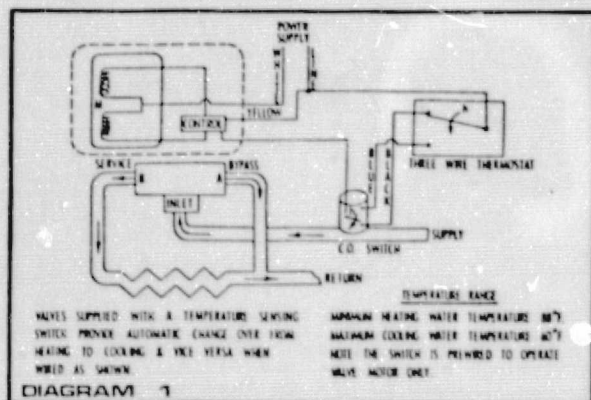


Diagram No. 1: Reversible motor valves, 552 and "BR" Series with temperature sensing switch. Requires constant power supply.

Diagram No. 2: Reversible motor valves, 552 and "BR" Series with 3-wire thermostat.

Diagram No. 3: Reversible motor valves, 552 and "BR" Series with 3-wire thermostat and end switch.

INVERTED FLARE TYPE CONNECTIONS FOR USE WITH 687 "BR" SERIES VALVES



VALVE BODY MACHINED TO RECEIVE ANY OF THESE FITTINGS:

- A. Inverted flare nut and elbow assembly, female, for 5/8" O.D. tubing Part No. 436A214-1. Length of fitting 15/16".
- B. Inverted flare nut and coupling assembly, female, for 5/8" O.D. tubing Part No. 436A220. Length of fitting 1 - 11/16".
- C. Inverted flare nut assembly, female, for 5/8" to 7/8" O.D. tubing Part No. 436A252. Length of fitting 1 - 27/32".
- D. Inverted flare nut and nipple assembly, male, for 5/8" O.D. tubing Part No. 436A229-3. Length of fitting 3".
- E. Inverted flare nut and elbow assembly, male, for 5/8" O.D. tubing Part No. 436A214-4. Length of fitting 1 - 15/16". Fits directly to shut-off valve.

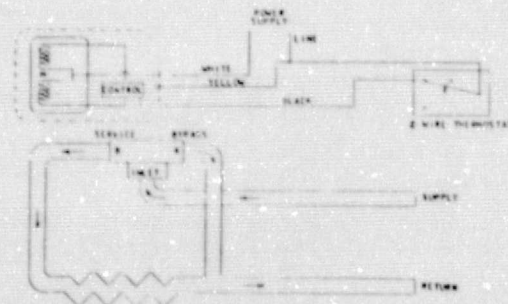


Diagram No. 4: Reversible motor valves, 552 and "BR" Series, having two-wire control option. Requires constant power supply.

C-2

Engineering and Installation reference notes

SPECIFICATIONS:

U.S. STANDARD

Electrical Rating	24 Volt, 50/60 Hz., (5.5 watt) 120 Volt, 50/60 Hz., (5.5 watt) 240 Volt, 50/60 Hz., (5.5 watt)
	(Other motor energizations available)
Electrical Wiring	Wire leads 18" long through a conduit fitting (No. 18AWG 105°C Appliance Wire)
Valve Body	Forged Brass
Rubber Goods	
300 Type	Compound for hot water and chilled water
400 Type	Compound for hot water and steam service
Temperature Limits	
300 Type	Water: 200°F, ambient temperature: 110°F
400 Type	Water: 250°F, ambient temperature: 150°F Steam: 16 PSI maximum system pressure
System Pressure	200 P.S.I. Maximum

"BR" SERIES

1/16" Port	50 P.S.I. opening or closing pressure differential
5/16" Port	100 P.S.I. opening or closing pressure differential
3/8" Port	200 P.S.I. opening or closing pressure differential

552 SERIES

2 way	B → A Flow	6" port	25 psi pressure differential
3 way	(Common Inlet)		
	Inlet → B	650" port	25 psi pressure differential
	Inlet → A	650" port	20 psi pressure differential
	Inlet → A	5" port	35 psi pressure differential
3 way	(Common Outlet)		
	A or B → outlet	650" port	15 psi pressure differential
	A → outlet	5" port	25 psi pressure differential

METRIC

Electrical Rating: Same as U.S. Standards

Electrical Wiring	Wire leads 45mm long through a conduit fitting (1.5 sq. mm 105°C Appliance Wire)
-------------------	---

Temperature Limits

300 Type	Water: 94°C, ambient temperature: 43°C
400 Type	Water: 121°C, ambient temperature: 82°C Steam: 1.05 kg/cm ² maximum system pressure

System Pressure: 14 kg/cm² maximum

15.2 mm Port	1.0 kg/cm ² opening or closing pressure differential
12.7 mm Port	2.1 kg/cm ² opening or closing pressure differential
11 mm Port	3.5 kg/cm ² opening or closing pressure differential
8 mm Port	7 kg/cm ² opening or closing pressure differential
5 mm Port	14 kg/cm ² opening or closing pressure differential

1. Suitable for static test up to 200 P.S.I. or 21 kg/cm²
2. Valve part numbers on 6070R do not include fittings. Fittings must be ordered separately.
3. In all cases on 2-way valves, flow should be from Port B to Port A.
4. Valves with field and switches are available with 18" leads only.
RATING: 5 AMP, 250 V A.C.

ERIE MANUFACTURING COMPANY

4000 S. 13th St., Milwaukee, Wis. 53221

Tel: (414) 483-7786 Telex: 2-6867

(Canada) Ltd. Box 880, Stouffville, Ont.

Erie-Clark-Europ N. V., Wolfstee B 2410 Herentals, Belgium

IMPORTANT NOTE FOR FAN COIL INSTALLATIONS

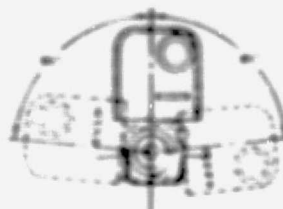
INSTALLATION

These high performance, high differential capability valves are motor driven both to the open and the closed position. A three-wire S.P.D.T thermostat is required, or a two-wire thermostat can be used when options 2, 3 or 6 are added. For optional control packages, 2, 3 or 6, a constant power source is required to the valve. (See wiring diagrams.)

TWO-WAY VALVES

When installing a two-way valve, the flow direction is from end B to end A. Port markings A and B are located on the bottom of the valve body.

MOUNTING



Valve motor and gear train will not function properly when wet. Motor housing must be protected from drippage. Motor housing need not be protected from condensation on its attached valve body when installed in horizontal piping. If valve is positioned within 90° of upright position. (See sketch.) Metric valves, like all other metering equipment are subject to failure and should be installed with dry air or nitrogen to enable quick and convenient servicing or replacement.

THREE-WAY VALVES

When installing three-way diverting valves, end B is the drive end and end A is the bypass end. The inlet port is unmarked. Port markings A and B are located on the bottom of the valve body. Three-way valves supplied with option 6 have wire control package and strap-on change-over switch provide automatic change over from heating to cooling and vice versa when wired as shown in diagram No. 1.

With water temperature of 88°F or higher, the valve will operate on the thermostat heating contacts. With water temperature of 60°F or lower, the valve will operate on the thermostat cooling contacts.

Three-way valves, fitted with a common outlet, are designed as shown in the specifications.

VALVES WITH SWEAT CONNECTIONS

The two asbestos protection shields must be used between the valve housing and the valve body to protect the mechanism and external wiring from flame and excessive heat. The asbestos shields are factory assembled and may be removed after leak testing. On valves with manual operator place lever in manually open position before soldering.

INSTRUCTIONS FOR SWEATING

Use only lead or tin base solder with melting point below 400°F. Do not overheat valve body.

Ends of water supply tubing must be thoroughly clean for a minimum distance of 1" from end.



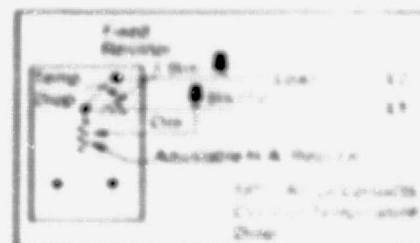
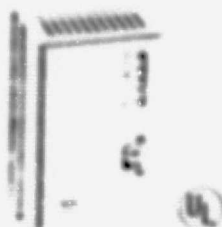
Product Information

Electric Room Thermostats TA-1501 AND TC1101, 1102, 1103, 1191

TA-1501

ELECTRIC CONTROLLER ROOM THERMOSTATS TWO-POSITION, HEATING

For on-off control with heat anticipation of low current devices such as actuators, relays and motor pull-up coils.



Bimetal operated snap action SPST switch. Copper coated 6" leads. 2 to 1 1/2" wide adjustable heat anticipation. Differential 2°F. Mounts on flush or surface switch box, or directly on wall (24 volt only). Dimensions: 4 3/8" high x 2 1/8" wide x 1 5/8" deep.

Part Number	Control Dial Range	Full Load Amps		Locked Rotor Amps		Pilot Duty VA
		24/120 Vac	240 Vac	24/120 Vac	240 Vac	
TA-1501	55-85°F (13-29°C)	1	1	6	6	24/120/240 Vac

ACCESSORIES

- AT 101 Lock cover kit
- AT 104 Dial stoppers
- AT 136 Title plates (play night heat cool)
- AT 504 Flange face cover kit (small)
- AT 505 Surface mounting base
- AT 546 Auxiliary mounting plate
- AT 602 Selector switch sub-base (9/41)
- AT 603 Selector switch sub-base one (9/41) one (9/41)
- AT 1102 3/4" guard
- AT 1104 Case aluminum guard
- AT 1105 Plastic guard
- AT 1155 Plastic guard
- AT 1165 Plastic guard
- Type 111 Control switch

OPTIONS Add dash number (XXX) suffix to base part number for dimensioning

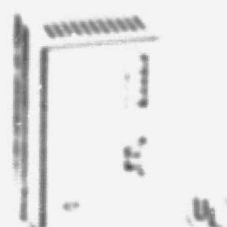


- 601 10°F night depression 120°F Fahrenheit dial & thermometer
- 602 10°F night depression 240°F Fahrenheit dial & thermometer
- 603 10°F night depression 240°F Fahrenheit dial & thermometer

(Maximum night depression is controlled by a centrally located time clock such as AT 174 or AT 175, or by selector switch sub-bases AT 602 or AT 603)



Bimetal operated snap action SPST switch. Copper coated 6" leads. Differential 2°F. Mounts on flush or surface switch box, or directly on wall (24 volt only). Dimensions: 4 3/8" high x 2 1/8" wide x 1 5/8" deep.



TC-1101/1102/1103 ELECTRIC CONTROLLER ROOM THERMOSTATS TWO-POSITION, HEATING AND/OR COOLING

For low or line voltage on-off control of fan coils, fans, motor starters and contactors.

Part No	Control Dial Range	Full Load Amps		Locked Rotor Amps		Pilot Duty (VA)
		24/120 Vac	240 Vac	24/120 Vac	240 Vac	
TC 1101	55-85°F (13-29°C)					40 @ 24 Vac
TC 1102	45-75°F (7-23°C)	4.4	2.2	26.8	13.2	210 @ 120/240 Vac
TC 1103	70-100°F (21-37°C)					

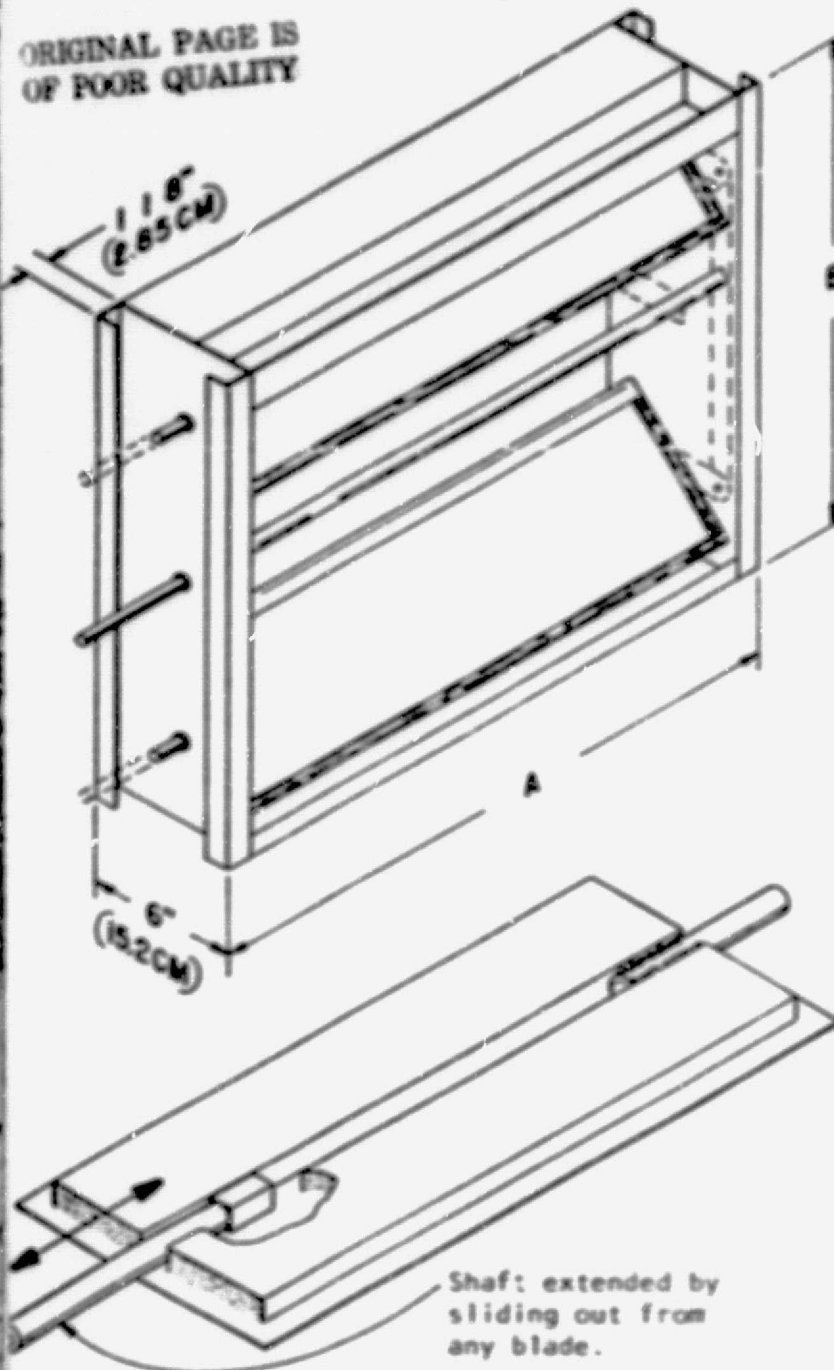
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MODEL

Tight Seal Damper-Insulated Blades Opposed Blade Operation

TSD-400-UD-1
TSD-400-UD-0

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SPECIFICATIONS

1. All welded construction.
2. Frame constructed of 14 ga. galvanized steel. Open beam type construction provides integral top & bottom blade stops.
3. Blades feature double skin construction with 14 ga. channel reinforcement welded between the skins, forming a structural closed beam; with full length thermal insulation.
4. Blades pivot on 1/2" (1.27cm) dia. CRS stub shafts in sintered bronze self-lubricating bearings.
5. Shaft extension feature is standard on any blade shaft.
6. Blade linkage is completely enclosed in the side frame.
7. Maximum blade span is 72" (183cm). Units with longer spans are made in multiple sections and require jack shafts.
8. Maximum blade deflection is 1/8" (.32cm) at center, for a 72" (183cm) long blade at 4" W.G.
9. Extruded neoprene & polyurethane is inserted in all blade edges and ends affording extremely efficient tight shut-off.
10. Maximum duct velocity is 3000 ft./min.
11. Maximum static pressure is 6" W.G. for a 72" (183cm) blade length.
12. Maximum height, for a single section, is 84" (213cm).



Shaft extended by
sliding out from
any blade.

MODEL NO.

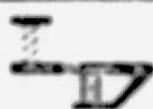
☐ TSD-400-UD-1

☐ TSD-400-UD-0

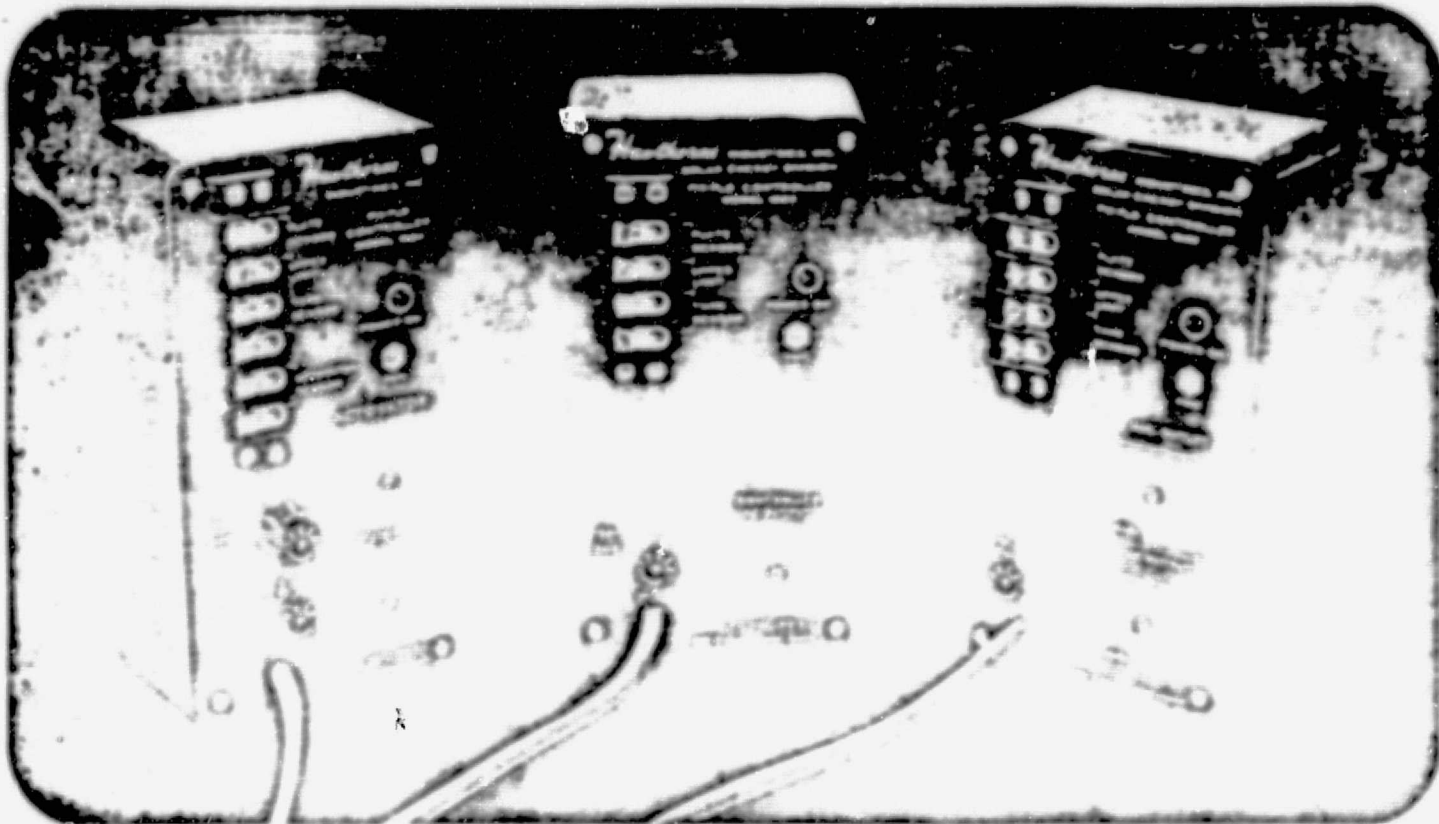
DESCRIPTION

Blade clip is shipped loose with thru bolts to permit positioning on any blade when actuator is mounted inside the duct.

Any shaft on the opposite side of the damper from the linkage may be extended as much as 6 inches from the blade to drive the damper when actuator is mounted outside the duct.

ITEM NO.	ARCHITECT	 LOUVERS & DAMPERS INC.
	ENGINEER	
	CONTRACTOR	
SEE SHEET 113-A72-LD FOR FULL SCHEDULE OF SIZES		
CUSTOMER P.O.	S.O. 96	DATE 3-2-76
		DWG 027-A76-LD

CUSTOM MANUFACTURERS OF LOUVERS, DAMPERS AND AIR CONTROL DEVICES



100% SOLID STATE DIFFERENTIAL TEMPERATURE CONTROLS FOR YOUR SOLAR SYSTEMS

A COMPLETE FAMILY OF VERSATILE, HIGH QUALITY CONTROLLERS WHICH PROVIDE A COST-EFFECTIVE SYSTEM COMPONENT FOR VIRTUALLY EVERY APPLICATION.

- Applied Research Laboratories safety tested and approved.
- Designed for simple installation with a minimum of labor.
- No professional trades required for installation.
- One year replacement warranty.
- 100% true solid state epoxy encapsulated circuitry.
- Maximum quality control--each unit is individually tested.
- Durable and attractive black phenolic case with black anodized aluminum face plate.
- Fused to protect circuitry from output overload.
- Power line surge and lightning protected.
- High reliability, low voltage sensors.
- 4 ampere (480 watt) controlled A.C. output.
- Stable operation on line voltage from 105-130 VAC.
- Transformer line isolation rated at 1600 VAC.
- No minimum or maximum wire length to sensor.
- Two standard sensors supplied with each differential control.
- Instant mounting with pressure sensitive backing material.

Hawthorne
INDUSTRIES, Inc.



SOLAR ENERGY DIVISION

CONTROL SYSTEMS - RESEARCH & DEVELOPMENT
1501 South Dixie West Palm Beach, Florida 33401

Phone 305/658-5400

Patent Pending Made in U.S.A.

100% SOLID STATE DIFFERENTIAL TEMPERATURE

MODEL # H 1500

THE ACTOVATOR

The H 1500 Actovator control is a low voltage controlled solid state switch to power auxiliary equipment in a solar system.

Typical Applications:

- Auto drain control for thermo-siphon solar systems as freeze protection (solenoid valves)
- To power a small heating element in a solar collector as frost protection.
- Switching unit to shift the output of a solar system from one storage tank to another at a predetermined temperature.
- Switching unit to turn on an auxiliary heating element to maintain a minimum temperature in a solar storage tank.
- To switch a solar home heating system from solar to conventional auxiliary heating at a predetermined temperature.
- Let your ingenuity be your guide.

Features:

- Low voltage control 5.1 VAC maximum short circuit current 4 ma
- Cutout may be selected for 120 VAC power normally on or off
- Controller power requirement 4 watts, 117 VAC, 60 HZ.
- Light emitting diode power on indicator
- 4 amp (480 watt) controlled output.
- Sensor activates or deactivates circuit by shorting

MODEL # H 1503

FIXFLO CONTROLLER

The Model #H 1503 Fixflo controller is a versatile solid state differential temperature control with the following features:

- 4 amp (480 watt) controlled A.C. output
- Positive on/off action for pump, relay or solenoid control (no chatter) no oscillation.
- $\pm 5^{\circ}\text{F}$ turn on differential.
- Linear control from 30° - 220°F .
- Sensor voltage 8.3 VDC maximum short circuit current 4.15 ma
- Low power requirement 4 watts, 120 VAC.
- Upper temperature limit control—stops pump circulation with a storage tank temperature of 165°F optional with added sensor.
- Frost cycle—starts pump circulation with a collector plate temperature of 35°F and will continue to circulate water from the storage tank until the plate temperature reaches 45°F , then stops and repeats this cycle as often as required to hold the collector above freezing (Note: not recommended in areas where very frequent freezing conditions occur). Optional with special sensor.

MODEL # H 1504

FIXFLO CONTROLLER WITH ACTOVATOR

The Model #H 1504 is identical to the #H 1503 Fixflo controller, with the addition of the features of the Model #H 1500 (the Actovator). In this unit, the normally on or normally off A.C. power is controlled by a normally open or normally closed sensor.

MODEL #H 1505

FIXFLO CONTROLLER WITH DUAL OUTLET

The Model #H 1505 is identical to the #1503 with the addition of an auxiliary (dual) outlet which may be used to power two pumps, one on either side of a heat exchanger, or operate a relay or solenoid valve.

MODEL # H 1510

VARI FLO CONTROLLER

The Model #H 1510 is a versatile solid state differential temperature controller with a variable flow rate feature.

This controller must be used with a pump that is speed controllable. The following pumps have been tested and found to perform well with the Model #H 1510 control.

March Model 821BR and 809

Teel Model 1P761* and 1P760

Sundstrand Model LA4302*

Grundfos Model UPS20-42F* and UP25-42S

Note *Cast iron pump housing. Do not use for direct circulation of domestic water.

The March Model 809 and Teel Model 1P760 pumps are not recommended for use with the Model #H 1510 control, even with a single panel installation, as their flow rates are already too low; thus, there is no advantage to speed control of these pumps. However, they do speed control, and may fit a special requirement.

The Model #H 1510 is a true differential temperature controller. The flow rate (speed) of the pump is controlled by the amount of differential. A very slow flow rate is started with a $3-4^{\circ}\text{F}$ differential and is increased to full pump flow when a $23-24^{\circ}\text{F}$ differential is reached.

URE CONTROLS FOR YOUR SOLAR SYSTEMS

THE ADVANTAGES OF AUTOMATIC FLOW RATE CONTROL ARE MANY

1. The proper flow rate through the solar collector is automatically adjusted based on the amount of energy to be gained, holding plate temperatures down and increasing overall system performance.
2. Eliminates frequent pump cycling, thus extending pump life.
3. All recommended pump motors operate at lower temperatures throughout their speed control range, extending expected pump life.
4. Only the energy required for efficient system operation is used resulting in a power savings.
5. System installation cost is lowered by eliminating the plumbing bypass around the pump commonly used to adjust for a desired flow rate.
6. The proper flow rate is automatically established, eliminating time-consuming bypass adjustments.

The #H 1510 Variflo control also offers upper temperature limit and frost cycle features as explained in the last 2 items of the #H 1503 with the optional sensors.

MODEL #H 1511

VARIFLO CONTROLLER WITH ACTUATOR

The #H 1511 Variflo control is identical to the #H 1510 with the addition of the features of the Actuator Model #H 1500. In this unit, the normally on or normally off A.C. power is controlled by normally open or normally closed sensors.

MODEL #H 1512

VARIFLO CONTROLLER WITH DUAL OUTLET

The Model #H 1512 Variflo controller is identical to the Model #H 1510 with the addition of an auxiliary A.C. outlet (dual outlet), which may be used to power two pumps, one on either side of a heat exchanger. (Note: This auxiliary outlet is also speed controlled and is not suitable for relay or solenoid valve control).

MODEL #H 1530

RELAY PACKAGE

The #H 1530 is an accessory for Models #H 1503 and #H 1500 controllers, extending output load capabilities to 1 h.p.

A must if pump motor has high starting current or running current above 4 amps.

The relay package comes complete with conduit mounting and A.C. line cord for connection to the controller.

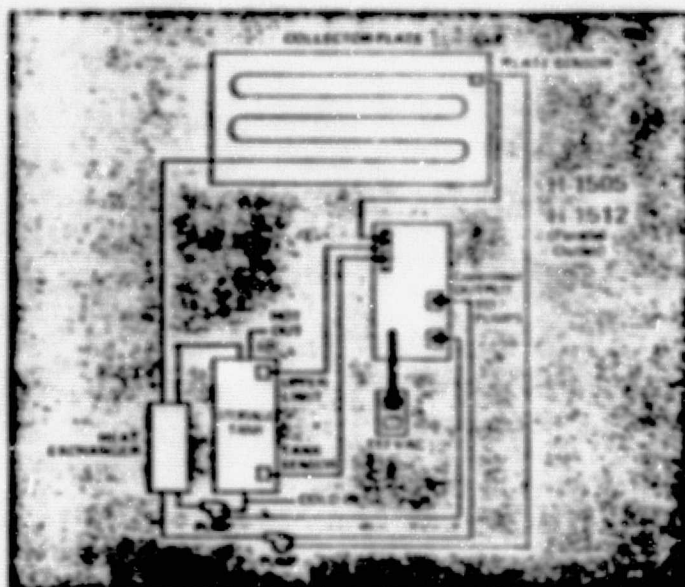
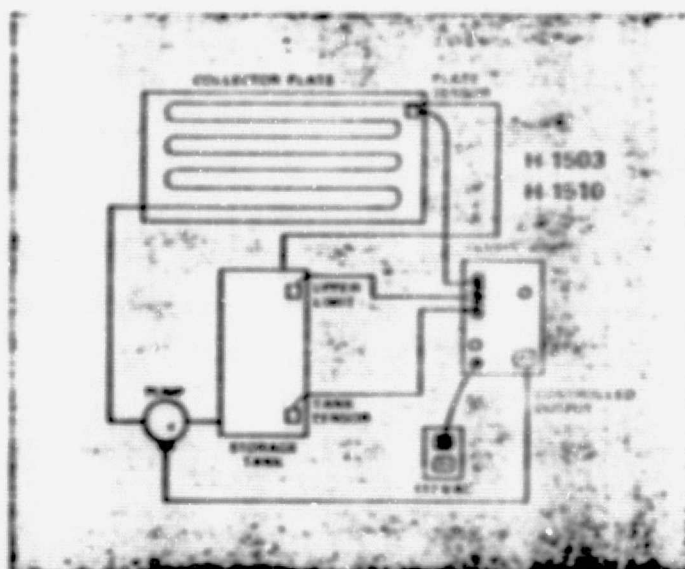
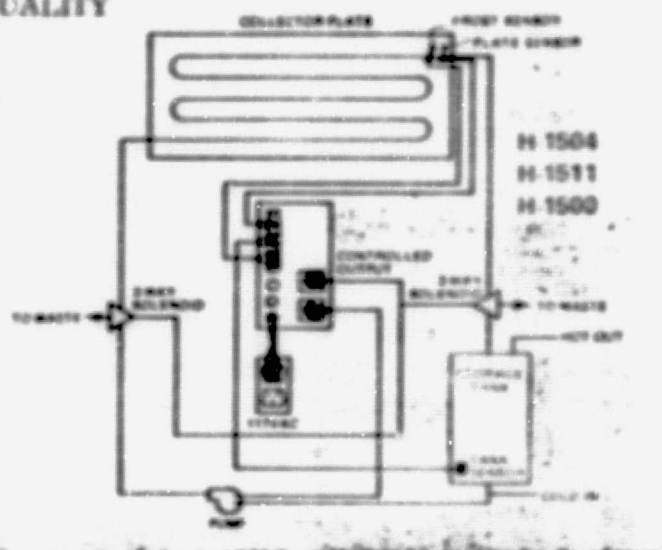
SENSORS

#H 1525 Standard thermistor sensor 10K ohm at 25°C, 1% curve matched.

OPTIONAL ACCESSORIES

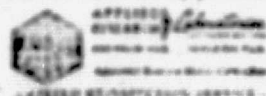
- #H 1514 Upper temperature limit 85°F. Pool
- #H 1515 Upper temperature limit 165°F. Hot water.
- #H 1520 Frost cycle sensor with thermistor 35°F.
- #H 1535 Mounting Plate
- #H 1540 Rain tite Cover

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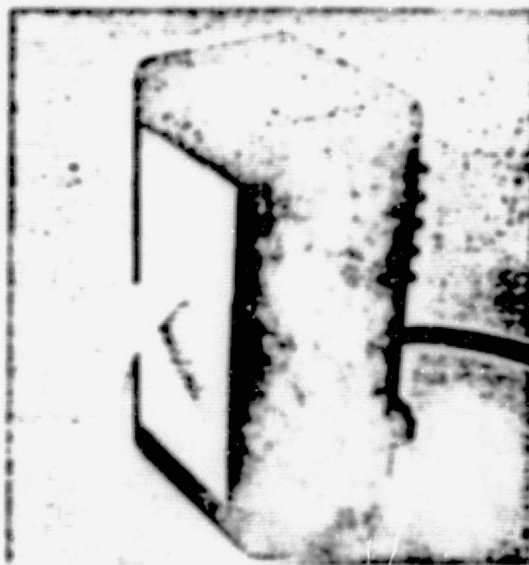
SPECIFICATIONS:

- Controller power requirement 117 VAC, 60 HZ
H-1500, H-1503, H-1505, H-1510, H-1512—4 watts
H-1504 and H-1511 —7 watts
- Power supply regulation for stable operation on power line voltages from 105—130 VAC, 60 HZ (all units).
- Transformer isolation from power line 1600VAC.
- Thermistor sensor voltages 8.3 VDC maximum short circuit 4.15 ma. Actovator sensor voltages 5.1 VAC, 60 HZ. Maximum short circuit current 4 ma.
- All sensor terminals are short circuit overload protected.
- Controlled A.C. output 4 amp. (480 watt) at 120 VAC overload protected with 4 amp. 3 AG fuse.
- All units have varistor line spike and lightning protection.
- Fixflo controllers 5°F differential to turn on.
- Variflo controllers 3—4°F start with 20°F span to full on.
- Indicator lamp solid state light emitting diode.
- Controller case durable phonolic thermo plastic with black anodized aluminum face plate and white epoxy silk-screen lettering. Case dimensions 6" x 3 1/4" x 2 1/4".
- Sensor case black anodized aluminum or nickel plated copper.
- All circuitry self-extinguishing epoxy encapsulated.
- Shipping weight — 2 lbs.
- All units Applied Research Laboratories approved. Test #21588.



WARRANTY

This controller is warranted against defects in workmanship or materials under normal use for one year from date of purchase. Liability in all events is limited to purchase price paid and liability under the aforesaid warranty is limited to replacing or repairing any part or parts which are defective in material or workmanship and are returned to our factory, shipping cost prepaid. No other warranty, expressed or implied, nor representation of merchantability or of fitness for a particular purpose, except as set forth in this warranty, is made or authorized by Hawthorne Industries, Inc.



Extremely strong, pressure sensitive foam tape on the back of the controller case provides for instant mounting of the unit.



SOLAR ENERGY DIVISION

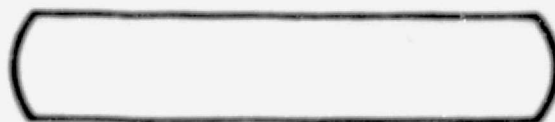
CONTROL SYSTEMS RESEARCH & DEVELOPMENT

1501 South Dixie West Palm Beach, Florida 33411

TELEPHONE 365-5000



WaterBank I
MODEL W14M



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**Uses house heating boiler to provide
plenty of hot water for all family needs.**

FEATURING:

Ample storage: 40 and 52 gallon models.

Thermostatically controlled water temperature.

Easily adjustable.

Self contained circulating pump with corrosion proof
bronze waterways. (WaterBankN)

Easy to install. No chimney connection needed. Pump and
controls are completely wired at factory.

WaterBank I stores hot water from the tankless coil in the house
heating boiler.

WaterBank II heats water, using boiler water for heat source.
No tankless coil needed.

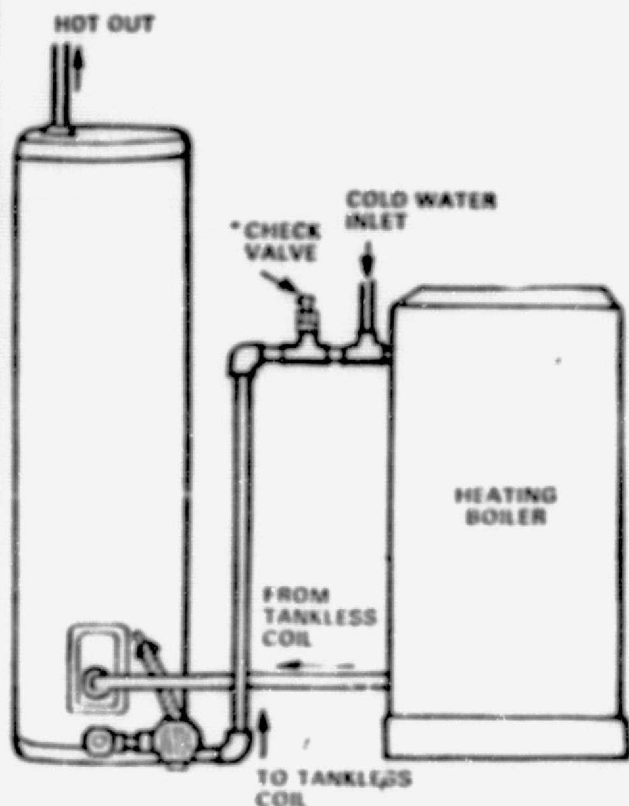
5 YEAR GUARANTEE

Complete tank assembly (less circulating pump) exchanged free if
tank leaks in first five years. (One year if heater is used in other
than one family dwelling.) All other components guaranteed against
defects in material or workmanship for one year. Complete details
and conditions on guarantee certificate available from company
on request.

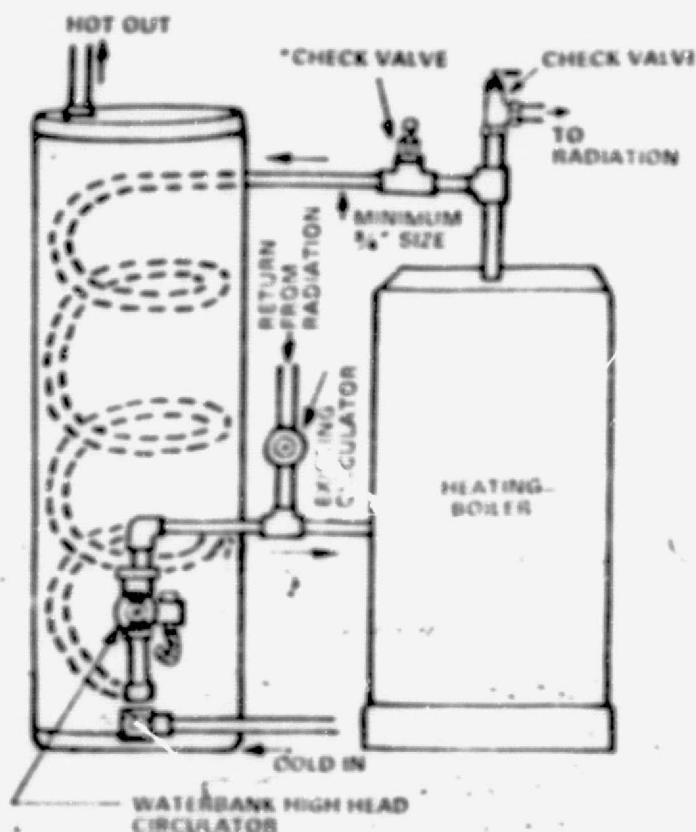
THE GLASS-LINED WATER HEATER CO.

13000 ATHENS AVENUE / CLEVELAND, OHIO 44107 / 216 • 521-1377

WaterBank I



WaterBank II



*USE SPECIAL WATERBANK CHECK VALVE TO PREVENT CHATTERING.

WATERBANK I	WATERBANK II	CIRCULATOR	HEIGHT	DIAMETER	TANK CAPACITY
W14M		MARCH	59 3/4"	16"	40 GAL.
W14T		TACO	59 3/4"	16"	40 GAL.
W15M		MARCH	59 3/4"	18"	52 GAL.
W15T		TACO	59 3/4"	18"	52 GAL.
	W25S	SUNDSTRAND	59 3/4"	18"	52 GAL.

THE GLASS-LINED WATER HEATER CO.

Advanced Engineering in Water Heaters

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